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Assessment of Heavy Metal Contamination and Its Indexing Approach for Pond Water in Angul District, Orissa, India

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Abstract: The study was carried out in Angul–Talcher region of Orissa to investigate the metal contamination in various ponds. In order to achieve the objective, fourteen water samples were collected from ponds during summer and winter seasons. The concentrations of trace metals such as Cd, Cr, Cu, Co Fe, Mn, Ni, Pb, Hg and Zn were determined by using Atomic Absorption Spectrophotometer (AAS). The obtained data is used for calculating the heavy metal pollution index (HPI) to know the existing water quality status of ponds. The maximum value of HPI was 79.01 and 63.83 in summer and winter season respectively, which is below the critical index limit of 100. Hg and Cr could not be detected in any sample of the study area.

Key words: Pond water, seasonal variation, heavy metal pollution index.

Introduction

Surface water is an essential component of the natural environment and a matter of serious concern today. The growing urbanization and ever increasing anthropogenic influences have been constantly exerting pressure on water bodies (White and Rasmussen, 1998). Ponds are considered to be one of the most productive and biologically rich surface water eco-system (Sharma, 1998). The pond water plays a major role in the socio-economic growth of nearby rural and sub-urban people, due to its frequent use in domestic, agricultural, fishery and other purposes. Increasing pond water pollution causes not only the deterioration of water quality but also threatens human health, balance of aquatic eco-system, economic development and social prosperity (Mustapha, 2008).

Trace metals enter ponds from variety of sources; it can either be natural or anthropogenic (Bem et al., 2003; Wong et al., 2003; Adaikpoh, 2005; Akoto et al., 2008). Usually in unaffected environments the concentration of most of the metals is very low and is generally determined by the mineralogy and the weathering of that area (Karbassi et al., 2008). Non-point sources are the great contributors of metal concentration to the pond water. Industrial discharge, domestic sewage, run-off from agricultural, urban and mining areas, and atmospheric precipitation are the main sources of toxic heavy metals that enter aquatic system (Khan et al., 2005).

Generally pond water is contaminated with heavy metals by various anthropogenic activities such as domestic waste water, agricultural run-off, mining and associated industrial activities (Celine et al., 2007; Khan et al., 2005; Mohanty et al., 2001; Sahu, 1998). Improper disposal of toxic solid or liquid waste in open or barren land, may result in their contamination of the nearby water bodies (Khan et al., 2005). The heavy metals contamination of aquatic ecosystems is a major

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environmental problem. Some of these metals are potentially toxic or carcinogenic at very low concentration in affecting the aquatic life. The heavy metals retain in the water for long time and tend to accumulate in the aquatic organisms through food chain (Konhauser et al., 1997; Vega et al., 1998).

The accumulation of metals in an aquatic environment has direct consequences to pond ecosystem and nearby population including cattle. Some of the metals such as Zn, Fe, Ni, Mn and Cu are the essential micronutrients required for metabolic activity in organisms to sustaining aquatic biodiversity, but there is a narrow gap between their essentiality and toxicity (Celine et al., 2007). While many other metals such as Cd, Cr, Pb and Co have no known physiological activities (Aktar et al., 2010; Kar et al., 2008). Metals are non-degradable, and can accumulate through the different tropical levels causing a deleterious biological effect to the aquatic environment (Celine et al., 2007; Reza and Singh, 2010).

Pond water with high metal contents has a serious contribution to the pollutant dispersion in soil and ground water. At various places the residents of rural areas use the pond water for bathing, washing clothes and utensils, irrigation and several other domestic purposes. Considering all these aspects, it was important to monitor the pond water quality with respect to heavy metal contamination in the study area.

Study Area

The study area (Angul–Talcher region) lies between latitudes 20º37′ N to 21º10′ N and longitudes 84º53′ E to 85º28′ E and situated at an average height of 139 metres above mean sea level (MSL). The area comes under sub tropic monsoon climate with an average annual rainfall of 1370 mm. The temperature varies from 11.9ºC to 44.4ºC (Sundaray et al., 2006). The area has many important natural resources, which include coal, forests, fertile land, minor minerals, ground and surface water, etc. Due to availability of those natural resources, the area has been industrially developed. At present several large and medium scale industries such as Nalco Smelter and its Captive Power Plant (CPP-960MW), Super Talcher Thermal Power Station (STTPS-3000MW), Talcher Thermal Power Station (TTP-460MW), Iron and Steel industries and various coal mines are operational in the area. The drainage pattern is controlled by river Brahmani. These mining and other industrial activities can affect the various components of environment including pond water in surrounding area.

Materials and Methods

The water samples were collected from fourteen different ponds to evaluate the heavy metal contamination during summer and winter seasons in Angul–Talcher region. 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 from 10 to 15 cm below the water surface using acid washed plastic container to avoid unpredictable changes in characteristic as per standard procedures (APHA, 1998). Summer samples were collected in May 2007 and winter samples in January 2008. Care was taken to collect subsequent samples from same location during both the season. The collected samples were filtered (Whatman No. 42) and preserved with 6N of HNO_3 for further analysis (APHA, 1998). 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, 279.5 nm for Mn, 213.9 nm for Zn, 324.7 nm for Cu, 232 nm for Ni, 228.8 nm for Cd, 357.9 nm for Cr, 217 nm for Pb, 240.7 nm for Co and 253.7 nm for Hg.

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 (S_i) 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).

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.

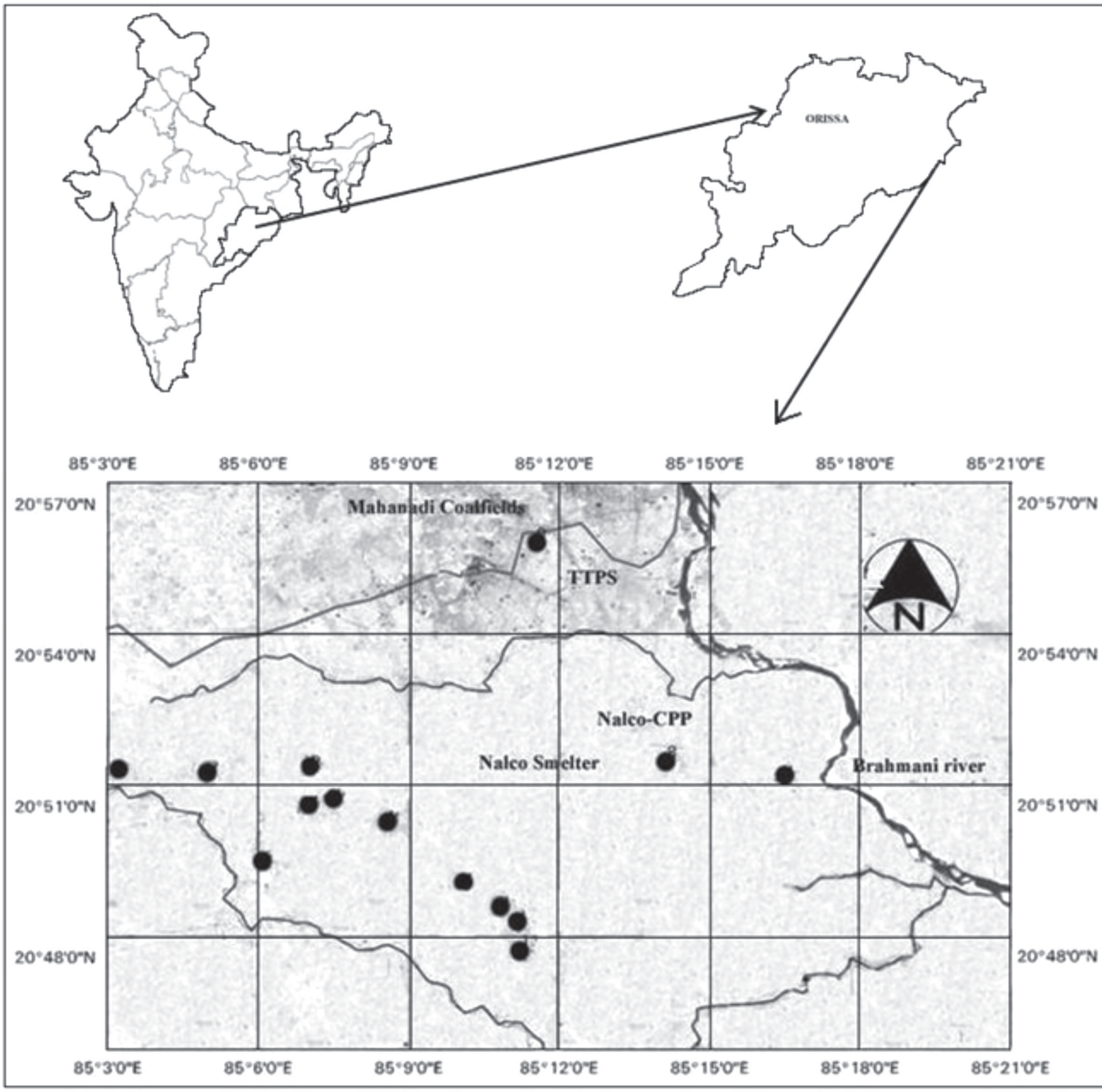

Figure 1: Map of study area along with sampling locations.

Table 1: Details of sampling locations along with their longitude and latitude

Sample Code	*Locations*	*Longitude*	*Latitude*
W11	Manapur pond water near Beragadia village	85°16′3° ″	20°51′11″
W12	Hakimpara pond water near Jagannath temple	85° 06′06″	20°49′31″
W13	Kumanda village, pond water	85°05′02″	20°51′15″
W14	Vikash Nagar, Angul, pond water	85°07′04″	20°50′42″
W15	Raniguda village, pond water	85°07′00″	20°51′28″
W16	Kandasaar village pond water	85°08′36″	20°50′15″
W17	Derjang reservoirs	85°01′57″	20°51′02″
W18	Pond water near Manapur village	85°14′10″	20°51′29″
W19	Pond water near Jagannathpur village	85°11′30″	20°55′48″
W20	Pond water near Turang village	85°07′30″	20°50′50″
W21	Nuashahi pond water	85°11′14″	20°47′50″
W22	Tulashi pal pond water	85°11′12″	20°48′14″
W23	Longibeda pond water	85°10′51″	20°48′37″
W24	Gadara khai pond water	85°10′11″	20°49′04″

Individual quality rating is given by the expression

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

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

The heavy metal pollution index (HPI) is then calculated as follows

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

where Q_i is the sub index of ith parameter. W_i is the unit weightage for ith parameter, n is the number of parameters considered. Generally, the critical pollution index value is 100.

Results and Discussion

Statistical analysis showed that the metal concentrations were significantly different for each sampling station but in most of the samples, the heavy metal concentrations were found within the permissible limit (IS: 10500). Zn, Cu, Pb and Cd are common pollutants, which are widely distributed, in the aquatic environment. Their sources are mainly from weathering of minerals and soils, atmospheric deposition, domestic effluents and urban storm water runoff (Fatoki et al., 2002).

The results (Table 3) showed that the average concentrations of Fe, Mn, Co, Cd, Zn, Pb, Ni and Cu were varied with the point of sampling at each location. The metals concentrations being higher during the summer season than winter season. Most of the samples of pond were found within the permissible limit (IS: 10500) except iron (Fe). The high Fe concentration may be assigned to the soil-water interaction because the almost stagnant pond water facilitate the dissolution of ions (Venugopal et al., 2009).The maximum concentration of Fe was found 0.480 and 0.350 mg/l during summer and winter season respectively. Pb was found within permissible limit in both seasons. It may be due to the less solubility of Pb containing minerals water (Venugopal et al., 2009). The maximum concentration was 0.0271 mg/l in winter season. The main source of Pb in pond water was domestic waste and urban run- off (Neal et al., 2000; Bordalo et al., 2001). The low values of Cu indicate there is no significant source of pollution. The maximum Cu was found 0.0063 mg/l and 0.0036

Table 2: HPI calculations for the pond 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)*
	Summer	*Winter*		
Pb (µg/l)	23	23	50	0.7588
Cd (µg/l)	1	0.5	10	3.7939
Zn (µg/l)	2.6	1.5	15000	0.0026
Cu (µg/l)	3.6	2.4	1500	0.0253
Fe (µg/l)	17.9	13.6	1000	0.0381
Mn (µg/l)	2.8	2.2	300	0.1265

Table 3: The concentrations range, mean and standard deviation of individual metals

Parameters	*Summer*		*Winter*	
	Range	*Mean ± Sd*	*Range*	*Mean ± Sd*
Pb (mg/l)	<0.01–0.0270	0.0230 ± 0.0057	<0.01–0.0271	0.0230 ± 0.0057
Cd (mg/l)	<0.00004–0.0026	0.0010 ± 0.0011	<0.00004–0.0006	0.0005 ± 0.0001
Zn (mg/l)	0.0007–0.0063	0.0026 ± 0.0022	<0.0004–0.0041	0.0015 ± 0.0013
Cu (mg/l)	<0.001–0.0063	0.0036 ± 0.0019	<0.001–0.0036	0.0024 ± 0.0011
Ni (mg/l)	<0.009–0.0437	0.0170 ± 0.0121	<0.009–0.0334	0.0130 ± 0.0082
Fe (mg/l)	<0.005–0.0480	0.0179 ± 0.0136	<0.005–0.0350	0.0136 ± 0.0098
Co (mg/l)	<0.004–0.0093	0.0077 ± 0.0023	<0.004–0.0082	0.0057 ± 0.0022
Mn (mg/l)	<0.0015–0.0041	0.0028 ± 0.0012	<0.0015–0.0032	0.0022 ± 0.0008
Hg (mg/l)	<0.00005	—	<0.00005	—
Cr (mg/l)	<0.003	—	<0.003	—

mg/l in respective seasons. It may be attributed to domestic sewage and run-off from farmed areas (Wu et al., 2008). The concentration of zinc was very low in all the samples as compared to its permissible limit. It was 0.0063 mg/l and 0.0041 mg/l during summer and winter, respectively. It is attributed to the presence of unused remains of zinc sulphate in fertilizers (Wu et al., 2008) and effluent from metal alloys industries (Brian, 2009). The trace of Cd has been found to be toxic to fish and other aquatic organisms (Fatoki et al., 2002). The Cd concentration in ponds water were found almost negligible, it may be due to the dispersion along a great distance from coal based power plants and other metal industries (Brian, 2009). Presence of Mn concentration was also very less. The maximum value was 0.0041 mg/l and 0.32 mg/l in summer and winter respectively. The maximum values of Ni and Co were 0.0437 and 0.0092 during summer season. Hg and Cr were not detected in any of the samples in the study area.

In order to calculate the HPI of water, the mean concentration value of the selected metals, namely Pb, Cd, Zn, Cu, Fe and Mn have been taken into account (Prasad and Mondal, 2008; Reza and Singh, 2010). The detailed calculation of HPI with unit weightage (W_i) and standard permissible value (S_i) are presented in Table 2. The maximum HPI values were found to be 79.01 at Longibeda pond water (W23) followed by 44.0 at Pond water near Jagannathpur (Lachhanpur) village (W21) and 41.0 at Pond water near Turang village (W22) during summer. It may be due to the dissolution of metals from soil-water interaction. The values of HPI are found below the critical pollution index (100), as it has been reported that the water will be considered unacceptable with respect to heavy metal pollution if HPI values exceeds 100 (Prasad and Kumari, 2008; Reza and Singh, 2010). Since 100 is the critical point of HPI, it is meaningful to assume 50 is the critical mean of the HPI. When the HPI value exceeds 50, it can be said that the metal concentration has already attained the level to have the tendency of prevailing the critical limit even though the concentration is within the limit. The graph (Figure 2) shows that water quality of Nuashahi pond water (W23) with respect to the heavy metals concentrations have already attained the level to have the tendency of prevailing the critical limit. The water quality of pond water near Jagannathpur (Lachhanpur) village (W21) and pond water near Turang village (W22) have reached an alarming point.

Conclusion

The present study reveals that almost all the dissolved heavy metals concentrations were slightly high during the summer period than winter season. The study showed that the non-point sources are the major contributor of metal contamination in pond water in that region. However, almost all the metal concentrations in pond water samples were found within the permissible limit while Fe evidenced slightly higher values in both seasons.

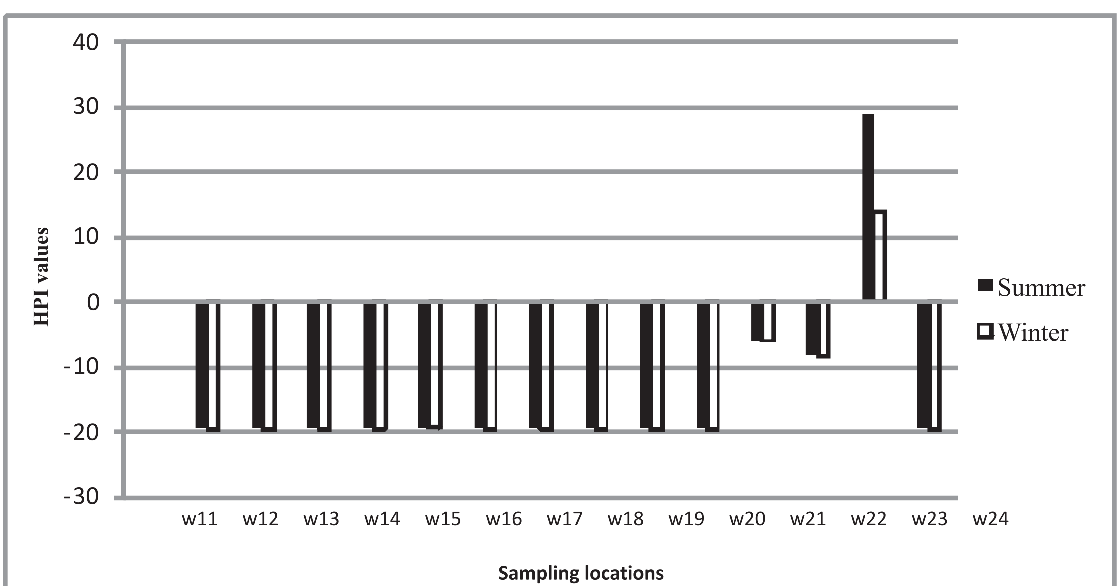

Figure 2: Deviation of HPI from mean value for summer and winter seasons.

It is attributed to the soil-water interaction and agricultural land use pattern around the ponds.

On the basis of HPI, the maximum value of HPI was found to be 79.01 and 63.83 in summer and winter, respectively. It indicates that the water samples are not critically contaminated with respect to heavy metals, however mitigative measures need to be taken for protecting the pond water quality.

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Calendar of Events

Water 2011
11 to 12 October 2011
London, United Kingdom
Website: http://marketforce.eu.com/Conferences/water11/?utm_source=conferencealerts.com&utm_medium=CA_ad&utm_campaign=water11
Contact name: Harry Morton
Organized by: Marketforce

The 6th China International Water Business Summit
13 to 14 October 2011
Beijing, China
Website: http:// www.cdmc.org.cn/2011/water/
Contact name: Amy ren
Organized by: cdmc

3rd Symposium on Environmental Management - Towards Sustainable Technologies
26 to 28 October 2011
Zagreb, Croatia (Hrvatska)
Website: http://www.sem-eco.com.hr
Contact name: Hrvoje Kusic
Organized by: Faculty of Chemical Engineering and Technology, University of Zagreb, and Croatian Society of Chemical Engineers

The 2011 International Conference on Sustainable Development (CSD)
28 to 30 October 2011
Shanghai, China
Website: http://www.engii.org/cet2011/CSD2011.aspx
Contact name: Tina
Organized by: Tongji University

14th International World Lake Conference
31 October 2011 to 4 November 2011
Austin, Texas, United States
Website: http://www.wlc14.org
Contact name: Hayat Qurunful
Organized by: River Systems Institute

Water Resource Sustainability Issues on Tropical Islands
14 to 16 November 2011
Honolulu, Hawaii, United States
Website: http://sites.google.com/site/wrrcconference2011/
Contact name: Aly El-Kadi
Organized by: Water Resources Research Center

The 2011 International Conference on Water, Energy, and the Environment
14 to 17 November 2011
Sharjah, United Arab Emirates
Website: http://www.aus.edu/conferences/icwes/
Contact name: Raafat Alnaizy
Organized by: American University of Sharjah

GIWEH – Water and Environment in a Changing World – Global Innovation outlook
20 to 24 November 2011
Marrakesh, Morocco
Website: http://www.icwre.com
Contact name: Nidal Salim
Sponsored by: GIWEH- Global Institute for Water Environment and Health

IWA Development Solutions Congress
21 to 24 November 2011
Kuala Lumpur, Malaysia
Website: http://www.iwa2011kl.org/
Contact name: Adrian Puigarnau
Organized by: Malaysian Water Association

First International Conference on Water and Society
5 to 7 December 2011
Las Vegas, Nevada, United States
Website: http://www.wessex.ac.uk/11-conferences/waterandsociety-2011.html
Contact name: Alice Jones
Organized by: Wessex Institute of Technology

Water Management in Mining 2011
7 to 8 December 2011
Perth, WA, Australia
Website: http://www.waterinmining.com.au
Contact name: Judy Hizon
Organized by: IQPC/Mining IQ

International Conference on Chemical, Ecology and Environmental Sciences (ICCEES'2011)
17 to 18 December 2011
Pattaya, Thailand
Website: http://psrcentre.org/listing.php?subcid=25&mode=detail
Contact name: P. S. Sandhu
Organized by: Planetary Scientific Research Centre