Assessments of trace metal bio-accumulation in Lamellidens marginali bivalve of Sirpur and Bilawali Lakes of Indore *(M.P.) India*

Mohd Abas Mantoo[1*], Shailendra Sharma[2], Rekha Sharma[1]
[1]Department of Zoology, Govt. Holkar Science College, Indore (M.P.) India
[2]P.G. Department of Zoology, Adarsh Institute of Management Science, Dhammod (M.P.) India

Abstract

Higher concentration of heavy metals makes harmfully affect to population live in water bodies. These are non-biodegradable and are persistent in nature. This is transferring through accumulation in lower trophic organisms to higher trophic organism through food chain and leads to terrible effect on ecological balance of environment and diversity of aquatic organisms and extended to different ecosystem. This is a study of determination the level of heavy metals Zn, Hg, Mn, Cu and Pb in surface water, soil sediments and whole soft body tissues of bivalve species *Lamellidens marginalis* inhabiting in Sirpur Lake and Bilawali talab of Indore district during summer, winter and monsoon seasons. Results indicate that mean highest values of concentrations of heavy metals in body, metal body burden and BWAF and BSAF in dry soft body tissues of all sampled bivalve species collected from Sirpur Lake Site A than Sirpur Lake Site B, Bilawali talab Site A and Bilawali talab Site B. This was due might be exposure of higher pollutant at that sampling sites.

Keywords: Water bodies, trace metals, bivalves, bio-accumulation, pollution.

Introduction

Water quality is going to change due to pollution did by human settlement near to water bodies. Waste water effluent comprising heavy metals, which leads to degradation of water quality and also adversely affect to ecosystem of such water bodies. Heavy metals viz. As, Zn, Cu, Pb Cd, Hg, Ni and Cr are some trace metals present in polluted water. Higher concentration of these heavy metals makes harmfully affect to population of water bodies. Heavy metals can accumulate by algae as primary consumer and transmitted across the higher levels of the food chain results into spreading of pollutants from origin to human. Presence of heavy metals in ponds, Lakes, dams, ditches, rivers and other water bodies affects the population depend on these water bodies for their needs. Consumption of aquatic food of those water bodies also toxic and are hazards to health. These can also be transferred through food chain (Choudhary *et al.,* 2014). A quality potable water supply is also a challenge in this century to fulfill the all requirement population (Schwarzenbach *et al.*,

2010). Different study has shown that metal shave ability to bio-concentrate in organisms directly from the water and bioaccumulate withinfood chains. This may causes the higher tropic organisms to suitcontaminated with higher concentrations of toxic metals (Hargrave *et al.*, 2000; Lee *et al.*, 2000; Boran &Altinok 2010; Shariati *et al.*, 2011). Heavy metal contamination is being recognized as melodramatic in large parts of thedeveloping countries, particularly in India, China and others (Meharg, 2004; Cheng, 2003). Contamination done by non-essential chemicals or/and elements in dietary substances is a series and adverse effects on human body and animals (D'Souza and Peretiatko, 2004). Therefore, in the present study of freshwater bivalves *Lamellidens marginalis* was selected to establish a local environmental monitoring network using bivalves as bio-indicator species to evaluate the trends of bioaccumulation of Zn, Cu, Pb and Cd in freshwater ecosystem.

Materials and Methods

Sirpur Lake and Bilawali talab of Indore, Madhya Pradesh was taken for this study. Surface water, sediments soil and *Lamellidens marginalis* bivalves were sampled from two different sites of each water bodies in summer, monsoon and winter season. Preparation of bivalve soft tissues for heavy metal analysis: Collected bivalves were dissected within 12 hours of collection and their whole soft body tissues were removed, washed in distilled water and dried separately in oven at about 70^0-80^0C. After oven drying dry weight of the tissue was measured. The tissues were powdered and stored separately by labeling the specimen with date, species name and sampling site name. 500mg dry powders of whole soft body tissue of bivalves were digested in 10ml mixture of Nitric acid: Perchloric acid in 5:1 ratio. After half hour stirring the samples were left overnight and were digested on hot plate till the clear white fumes appeared. 10ml volume of solution was maintained by adding acidic mixture of Nitric acid: Perchloric acid drop by drop. After allowing the flask to cool, double glass distilled water was added to bring the volume to 50 ml in volumetric flask and then solution was filtered through Whatman filter paper number 41. Surface water and soil sediments were also similarly processed. Heavy metals analysis: Heavy metal concentrations in surface water, soil sediment and whole soft body tissue of bivalves was carried out by using Atomic Absorption Spectrophotometer (AAS) (Thermo Scientific, U. K. make, Solaar A series model). Flame temperature of air–acetylene used for estimation of Zn, Cd, Cu and Pb was 1100ºC, 1000ºC, 2100ºC and 1200ºC respectively. While band path for Zn was 0.2 and for Cd, Cu and Pb was 0.5. Before each metal determination the AAS was calibrated for each metal using lower detection limit of AAS was 0.004mg/L for Zn and Cd,0.005mg/L for Cu and 0.003mg/L for Pb. All reagents used were A.R. grade (Merck). To avoid possible contamination, all laboratory equipments were washed in 10% HNO_3 solution and rinsed by distilled water prior to use. Procedural blanks and quality control samples prepared from solutions for Zn,

Cu, Cd and Pb, were analyzed after every 10 samples in order to check sample accuracy. Dry weight of each animal was used to calculate the metal concentration per unit body weight (µg/g) and metal body burden (µg/individual). Results are expressed as mean ± standard deviation (SD). All results are presented on a dry weight basis as µg/gm for heavy metal concentration. Metal bioaccumulation studies: To evaluate the efficiency of metal bioaccumulation in bivalve species, Biowater Accumulation Factor (BWAF) and Biosediment Accumulation Factor (BSAF) was calculated. The BWAF factor is defined as the ratio between the concentration of metal in the organism and that in the water. The BSAF is defined as the ratio between the concentration of metal in the organism and that in the sediments (Usero *et al.*, 2005; Szefer *et al.*, 1999).

BWAF = Concentration of heavy metal in animal tissue / Concentration of heavy metal in water

BSAF = Concentration of heavy metal in animal tissue / Concentration of heavy metal in soil sample

Results

Dry weight whole body, Metal concentration per unit body weight (µg/g), Metal Body burden (µg/individual), BWAF and BSAF were studied in reference to Zn, Cu, Pb and Cd heavy metals accumulation and presented in table 1.

Dry weight whole body:

Dry weight whole body with standard error in collected *Lamellidens marginali* bivalve samples of Sirpur and Bilawali Lake in summer, monsoon and winter seasons. Dry weight whole body with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 2.32±0.29 and 2.29±0.26 in summer; 2.84±0.32 and 2.69±0.25 in monsoon; 2.17±0.27 and 2.32±0.15 in winter seasons whereas, Bilawal Lake site A and site B were reported 2.18±0.19 and 2.21±0.22 in summer; 2.54±0.22 and 2.28±0.31 in monsoon2.19±0.18 and 2.18±0.19 in winter seasons respectively for all heavy metal accumulation.

Metal concentration per unit body weight (µg/g):

Metal concentration per unit body weight with standard error in collected *Lamellidens marginali* bivalve samples of Sirpur and Bilawali Lake in summer, monsoon and winter seasons. Concentration of Zinc per unit body weight with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 429.56±6.23 and 411.16±7.12 in summer; 301.45±7.26 and 297.84±6.20 in

monsoon; 334.19±5.69 and 302.18±6.87 in winter seasons whereas, Bilawal Lake site A and site B were reported 384.49±6.21 and 361.76±5.12 in summer; 239.56±4.85 and 246.49±4.12 in monsoon; 289.68±5.42 and 271.59±4.56 in winter seasons respectively. Concentration of Copper per unit body weight with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 128.76±2.36 and 113.24±2.17 in summer; 97.28±3.65 and 88.10±3.12 in monsoon; 116.24±3.57 and 99.75±2.45 in winter seasons whereas, Bilawal Lake site A and site B were reported 107.51±1.96 and 97.58±4.12 in summer; 81.47±2.64 and 73.24±3.02 in monsoon; 96.85±2.61 and 86.41±2.43 in winter seasons respectively. Concentration of Lead per unit body weight with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 109.24±1.98 and 106.46±2.10 in summer; 93.41±2.54 and 79.48±2.25 in monsoon; 107.58±3.12 and 95.78±3.72 in winter seasons whereas, Bilawal Lake site A and site B were reported 97.43±1.64 and 96.76±2.33 in summer; 76.58±1.95 and 63.15±1.86 in monsoon; 84.27±2.84 and 81.26±2.56 in winter seasons respectively. Concentration of Cadmium per unit body weight with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 24.23±0.59 and 16.10±0.23 in summer; 13.57±0.52 and 9.68±0.32 in monsoon; 17.49±0.12 and 12.57±0.34 in winter seasons whereas, Bilawal Lake site A and site B were reported 16.24±0.52 and 13.18±0.39 in summer; 10.12±0.28 and 7.34±0.19 in monsoon; 10.29±0.29 and 9.27±0.19 in winter seasons respectively.

Metal Body burden (µg/individual):

Different metal body burden per individual with standard error in collected *Lamellidens marginali* bivalve samples of Sirpur and Bilawali Lake in summer, monsoon and winter seasons. Metal body burden of Zinc per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 996.73±23.69 and 941.71±26.51 in summer 856.27±28.21 and 801.34±25.21 in monsoon; 725.34±20.19 and 701.21±22.42 in winter seasons whereas, Bilawal Lake site A and site B were reported 838.34±32.14 and 799.64±30.15 in summer; 608.6324±18.55 and 562.15±16.45 in monsoon; 634.55±19.87 and 592.22±20.19 in winter seasons respectively. Metal body burden of Copper per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 298.87±12.28 and 259.47±13.24 in summer; 276.42±10.20 and 237.14±9.23 in monsoon; 252.39±14.29 and 231.57±11.75 in winter seasons whereas, Bilawal Lake site A and site B were reported 234.52±11.28 and 215.80±12.69 in summer; 207.08±8.24 and 167.14±6.48 in monsoon; 212.25±10.23 and 188.52±8.65 in winter seasons respectively. Metal body burden of Lead per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 253.59±11.14 and 243.94±12.15 in summer; 265.44±9.10 and 213.95±8.56 in monsoon; 233.60±7.31 and

222.36±4.52 in winter seasons whereas, Bilawal Lake site A and site B were reported 212.55±11.43 and 213.99±10.42 in summer; 194.66±9.23 and 144.13±4.23 in monsoon; 184.70±3.85 and 177.30±3.02 in winter seasons respectively. Metal body burden of Cadmium per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 56.36±5.54 and 37.02±4.65 in summer; 38.69±2.59 and 26.19±3.10 in monsoon; 38.10±2.43 and 29.31±1.96 in winter seasons whereas, Bilawal Lake site A and site B were reported 35.55±4.53 and 29.28±2.15 in summer; 25.85±2.18 and 16.88±1.96 in monsoon; 22.68±1.57 and 20.36±1.28 in winter seasons respectively.

BWAF (Bio-water accumulation factor):

Bio-water accumulation factor of different metal per individual with standard error in collected *Lamellidens marginali* bivalve samples of Sirpur and Bilawali Lake in summer, monsoon and winter seasons. Bio-water accumulation factor of Zinc per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 3254.24±56.24 and 3590.92±61.92 in summer; 3360.65±52.14 and 4183.15±56.24 in monsoon; 2808.32±53.47 and 2695.63±52.51 in winter seasons whereas, Bilawal Lake site A and site B were reported 3511.32±63.25 and 3574.70±55.42 in summer; 3814.65±49.25 and 4121.91±42.56 in monsoon; 2834.44±51.24 and 2977.96±55.26 in winter seasons respectively. Bio-water accumulation factor of Copper per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 5234.15±64.12 and 5392.38±69.54 in summer; 5825.12±62.14 and 5912.75±65.14 in monsoon; 7801.34±47.91 and 6273.58±64.23 in winter seasons whereas, Bilawal Lake site A and site B were reported 5429.80±61.25 and 4978.57±59.23 in summer; 5903.62±52.67 and 6424.56±68.24 in monsoon; 6413.91±41.28 and 5684.87±43.10 in winter seasons respectively. Bio-water accumulation factor of Lead per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 3629.23±51.13 and 3596.62±55.43 in summer; 3485.48±51.12 and 1655.83±23.58 in monsoon; 5352.24±38.46 and 3941.56±34.29 in winter seasons whereas, Bilawal Lake site A and site B were reported 3805.86±44.23 and 4014.94±39.57 in summer; 3465.16±31.50 and 3255.15±30.58 in monsoon; 3813.12±52.10 and 3676.92±49.82 in winter seasons respectively. Bio-water accumulation factor of Cadmium per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 2817.44±34.29 and 2037.97±38.23 in summer; 1884.72±22.82 and 1402.90±20.15 in monsoon; 2301.32±19.75 and 1821.74±14.20 in winter seasons whereas, Bilawal Lake site A and site B were reported 2255.56±34.16 and 1967.16±29.21 in summer; 1510.45±18.25 and 1287.72±14.25 in monsoon; 1449.30±12.29 and 1343.48±11.29 in winter seasons respectively.

BSAF (Bio-sediment accumulation factor):

Bio- sediment accumulation factor of different metal per individual with standard error in collected *Lamellidens marginali* bivalve samples of Sirpur and Bilawali Lake in summer, monsoon and winter seasons. Bio- sediment accumulation factor of Zinc per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur

Table 1. Seasonal variations of heavy metals accumulation in *Lamellidens marginali* collected from Sirpur and Bilawali Lakes of Indore.

Parameters	Metal	Summer				Monson				Winter			
		Sirpur		Bilawali		Sirpur		Bilawali		Sirpur		Bilawali	
		Site A	Site B	Site A	Site B	Site A	Site B	Site A	Site B	Site A	Site B	Site A	Site B
Dry weight whole body	Zn	2.32± 0.29	2.29± 0.26	2.18± 0.19	2.21± 0.22	2.84± 0.32	2.69± 0.25	2.54± 0.22	2.28± 0.31	2.17± 0.27	2.32± 0.15	2.19± 0.18	2.18± 0.19
	Cu	2.32± 0.29	2.29± 0.26	2.18± 0.19	2.21± 0.22	2.84± 0.32	2.69± 0.25	2.54± 0.22	2.28± 0.31	2.17± 0.27	2.32± 0.15	2.19± 0.18	2.18± 0.19
	Pb	2.32± 0.29	2.29± 0.26	2.18± 0.19	2.21± 0.22	2.84± 0.32	2.69± 0.25	2.54± 0.22	2.28± 0.31	2.17± 0.27	2.32± 0.15	2.19± 0.18	2.18± 0.19
	Cd	2.32± 0.29	2.29± 0.26	2.18± 0.19	2.21± 0.22	2.84± 0.32	2.69± 0.25	2.54± 0.22	2.28± 0.31	2.17± 0.27	2.32± 0.15	2.19± 0.18	2.18± 0.19
Metal concentration per unit body weight(µg/g)	Zn	429.56± 6.23	411.16± 7.12	384.49± 6.21	361.76± 5.12	301.45± 7.26	297.84± 6.20	239.56± 4.85	246.49± 4.12	334.19± 5.69	302.18± 6.87	289.68± 5.42	271.59± 4.56
	Cu	128.76± 2.36	113.24± 2.17	107.51± 1.96	97.58± 4.12	97.28± 3.65	88.10± 3.12	81.47± 2.64	73.24± 3.02	116.24± 3.57	99.75± 2.45	96.85± 2.61	86.41± 2.43
	Pb	109.24± 1.98	106.46± 2.10	97.43± 1.64	96.76± 2.33	93.41± 2.54	79.48± 2.25	76.58± 1.95	63.15± 1.86	107.58± 3.12	95.78± 3.72	84.27± 2.84	81.26± 2.56
	Cd	24.23± 0.59	16.10± 0.23	16.24± 0.52	13.18± 0.39	13.57± 0.52	9.68± 0.32	10.12± 0.28	7.34± 0.19	17.49± 0.12	12.57± 0.34	10.29± 0.29	9.27± 0.19
Metal Body burden (µg/individual)	Zn	996.73± 23.69	941.71± 26.51	838.34± 32.14	799.64± 30.15	856.27± 28.21	801.34± 25.21	608.6324± 18.55	562.15± 16.45	725.34± 20.19	701.21± 22.42	634.55± 19.87	592.22± 20.19
	Cu	298.87± 12.28	259.47± 13.24	234.52± 11.28	215.80± 12.69	276.42± 10.20	237.14± 9.23	207.08± 8.24	167.14± 6.48	252.39± 14.29	231.57± 11.75	212.25± 10.23	188.52± 8.65
	Pb	253.59± 11.14	243.94± 12.15	212.55± 11.43	213.99± 10.42	265.44± 9.10	213.95± 8.56	194.66± 9.23	144.13± 4.23	233.60± 7.31	222.36± 4.52	184.70± 3.85	177.30± 3.02
	Cd	56.36± 5.54	37.02± 4.65	35.55± 4.53	29.28± 2.15	38.69± 2.59	26.19± 3.10	25.85± 2.18	16.88± 1.96	38.10± 2.43	29.31± 1.96	22.68± 1.57	20.36± 1.28
BWAF	Zn	3254.24± 56.24	3590.92± 61.92	3511.32± 63.25	3574.70± 55.42	3360.65± 52.14	4183.15± 56.24	3814.65± 49.25	4121.91± 42.56	2808.32± 53.47	2695.63± 52.51	2834.44± 51.24	2977.96± 55.26
	Cu	5234.15± 64.12	5392.38± 69.54	5429.80± 61.25	4978.57± 59.23	5825.12± 62.14	5912.75± 65.14	5903.62± 52.67	6424.56± 68.24	7801.34± 47.91	6273.58± 64.23	6413.91± 41.28	5684.87± 43.10
	Pb	3629.23± 51.13	3596.62± 55.43	3805.86± 44.23	4014.94± 39.57	3485.48± 51.12	1655.83± 23.58	3465.16± 31.50	3255.15± 30.58	5352.24± 38.46	3941.56± 34.29	3813.12± 52.10	3676.92± 49.82
	Cd	2817.44± 34.29	2037.97± 38.23	2255.56± 34.16	1967.16± 29.21	1884.72± 22.82	1402.90± 20.15	1510.45± 18.25	1287.72± 14.25	2301.32± 19.75	1821.74± 14.20	1449.30± 12.29	1343.48± 11.29
BSAF	Zn	1.94± 0.12	1.95± 0.19	2.06± 0.23	2.11± 0.12	1.87± 0.19	2.13± 0.24	1.99± 0.15	2.34± 0.16	1.52± 0.12	1.49± 0.17	1.64± 0.17	1.82± 0.13
	Cu	1.85± 0.10	1.88± 0.16	1.98± 0.21	1.97± 0.22	1.90± 0.20	1.78± 0.11	2.10± 0.27	2.27± 0.21	1.96± 0.15	2.05± 0.11	2.29± 0.13	2.36± 0.16
	Pb	4.12± 2.14	5.04± 2.22	5.10± 2.10	6.40± 0.24	4.44± 0.43	4.82± 0.23	5.26± 0.29	5.60± 0.36	4.65± 0.29	4.97± 0.22	4.85± 0.13	7.23± 0.18

	Cd	5.17± 3.45	4.01± 1.06	4.10± 1.95	4.38± 0.21	3.78± 0.32	3.01± 0.19	3.36± 0.10	2.49± 0.21	4.36± 0.18	3.74± 0.020	2.96± 0.16	3.07± 0.27

Lake site A and site B were 1.94±0.12 and 1.95±0.19 in summer; 1.87±0.19 and 2.13±0.24 in monsoon; 1.52±0.12 and 1.49±0.17 in winter seasons whereas, Bilawal Lake site A and site B were reported 2.06±0.23 and 2.11±0.12 in summer; 1.99±0.15 and 2.34±0.16 in monsoon; 1.64±0.17 and 1.82±0.13 in winter seasons respectively. Bio- sediment accumulation factor of Copper per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 1.85±0.10 and 1.88±0.16 in summer; 1.90±0.20 and 1.78±0.11 in monsoon; 1.96±0.15 and 2.05±0.11 in winter seasons whereas, Bilawal Lake site A and site B were reported 1.98±0.21 and 1.97±0.22 in summer; 2.10±0.27 and 2.27±0.21 in monsoon; 2.29±0.13 and 2.36±0.16 in winter seasons respectively. Bio-sediment accumulation factor of Lead per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 4.12±2.14 and 5.04±2.22 in summer; 4.44±0.43 and 4.82±0.23 in monsoon; 4.65±0.29 and 4.97±0.22 in winter seasons whereas, Bilawal Lake site A and site B were reported 5.10±2.10 and 6.40±0.24 in summer; 5.26±0.29 and 5.60±0.36 in monsoon; 4.85±0.13 and 7.23±0.18 in winter seasons respectively. Bio- sediment accumulation factor of Cadmium per individual with standard deviation in *Lamellidens marginali* bivalve samples collected from Sirpur Lake site A and site B were 5.17±3.45 and 4.01±1.06 in summer; 3.78±0.32 and 3.01±0.19 in monsoon; 4.36±0.18 and 3.74±0.020 in winter seasons whereas, Bilawal Lake site A and site B were reported 4.10±1.95 and 4.38±0.21 in summer; 3.36±0.10 and 2.49±0.21 in monsoon; 2.96±0.16 and 3.07±0.27 in winter seasons respectively.

Discussion

Results indicate that mean highest values of concentrations of heavy metals in body, metal body burden and BWAF and BSAF in dry soft body tissues of all sampled bivalve species collected from Sirpur Lake Site A than Sirpur Lake Site B, Bilawali talab Site A and Bilawali talab Site B. Reported higher metal concentrations and body burden in whole dry soft body tissues of all sampled bivalve species collected from Sirpur Lake Site A might be due to exposure of higher pollutant than other sampling sites. Shinde (2011) reported in his study that metal concentrations in the dry soft body tissues of mollusc were related to metal levels present in water bodies. Deshmukh (2013) also supported this report. Comprising of BWAF/BSAF values used to find most appropriate sentinel species to monitor heavy metal pollution in water. In this study BWAF values refers to concentration of a particular metal in a tissues of bivalve per concentration of that metal in water. Biosediment Accumulation Factor is defined as ratio of metal concentration in the bivalve tissues to that in sediment (Usero *et al.*, 2005; Szefer *et al.*, 1999). In monsoon, the heavy metal concentrations, metal body burden, BWAF and BSAF values in all bivalve

species were low in comparison to summer and winter seasons, this might be due to increased water level in water bodies (Patil and Pokhrel, 2004; Deshmukh, 2013).

References

Boran M. and Altinok N. (2010) A review of heavy metals in water sediment and living organism in the black sea. Turkish Journal of Fishries and Aquatic Science. 10: 565-572.

Cheng S.P. (2003) Heavy metal pollution in China: Origion, pattern and control. Environ. Sci. Pollut. Res. Int. 10: 192-198.

Choudhary P., Dhakad N.K. and Jain R. (2014) Studies on the Physico-Chemical Parameters of Bilawali Tank, Indore (M.P.) India. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT). 8(1.I): 37-40.

D'Souza C. and Peretiatko R. (2002) The nexus between industrialization and environment: A case study of Indian enterprises. Environ. Manag. Health. 13: 80-97.

Deshmukh G.M. (2013) Biomonitoring of heavy metal pollution of jayakwadi reserviour at Paithan by using bivalves as bioindicators. Ph.D. thesis submitted to Dr. BAM University, Aurangabad, (MS) India.

Hargrave B.T., Phillips G.A., Vass W.P., Bruecker P., Welch H.E. and Siferd T.D. (2000) Seasonality in bioaccumulation of organochlorines in lower trophic level Arctic marine biota. Environmental Science and Technology, 34(6): 980-987.

Lee C.S., Li X., Shi W., Cheung S.C. and Thornton I. (2006) Metal contamination in urban, suburban, and country park soils of Hong Kong. A study based on GIS and multivariate statistics. Sci Tot Environ. 356: 45-61.

Meharg A.A. (2004) Arsenic in rice- understanding a new disaster for south-east Asia. Trends Plant. Sci. 9:415-417.

Patil G.V. and Pokhrel K. (2004) Biomedical solid waste management in an Indian hospital: a case study. Waste Management. 25:592-599.

Schwarzenbach R.P., Egli T., Hofstetter T.B., von Gunten U. and Wehrli B. (2010) Global water pollution and human health. Annual Review of Environment and Resources. 35: 109-136.

Shariati S.R.P., Bonakdarpour B., Zare N. and Ashtiani F.Z. (2011) The effect of hydraulic retention time on the performance and fouling characteristics of membrane sequencing batch reactors used for the treatment of synthetic petroleum refinery wastewater. Bioresour. Technol. 102(17): 7692-7699.

Shinde S. Waykar B. and Deshmukh G.M. (2011) Bioaccumulation of metal in resh water pelecypod molluscs under experimental condition. The Bioscan. 6(4): 537-542.

Szefer P., Ali A.A., Ba-Haroon A.A., Rajeh A.A., Geldon J. and Nabrzyski M. (1999) Distribution and relationships of selected trace metals in molluscs and associated sediments from the Gulf of Aden,Yemen. Environ Pollut. 106: 299-314.

Usero J., Izquierdo C., Morillo J. and Gracia I. (2003) Heavy metals in fish (Solea vulgaris, Anguilla anguilla and Liza aurata) from salt marshes on the southern Atlantic coast of Spain. Environ Int. 29: 949-956.