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Assessment of the Metal Bioaccumulation in Three Species of Freshwater Bivalves

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Abstract The metal concentration and body burden of three species of fresh water bivalves, *Parreysia cylindrica, Parreysia corrugata* and *Corbicula striatella* were estimated in laboratory experiment after exposure to chronic concentration of arsenic (0.1719 ppm), cadmium (0.23 ppm), copper (0.13 ppm), mercury (0.06 ppm), lead (2.4 ppm) and zinc (5.1 ppm) separately up to 30 days. Dry weight of each animal was used to calculate metal concentrations (µg/g) and the metal body burden (µg/individual). It was observed that zinc, lead and copper concentration and metal body burden was highest in the *Corbicula striatella,* mercury and arsenic was highest in *Parreysia corrugata* and cadmium was highest in *Parreysia cylindrica.* Therefore, *Corbicula striatella* is being proposed as sentinel organism for monitoring of zinc, lead and copper*, Parreysia corrugata* for mercury and arsenic, and *Parreysia cylindrica* for cadmium in fresh water ecosystem.

Keywords Bivalves · Metal concentration · Body burden · Accumulation

Conventionally, metal monitoring of water has been carried out by analyzing the concentration of metals in water and sediments. However, information obtained through this method is inaccurate (Kennish 2000; Issam et al. 2003). Inaccurate information creates misleading decision-making for water quality assessment. To overcome this problem, the idea has been proposed to use a biomonitoring organism to indicate metal pollution. During the past few decades, many species have been studied to determine their potential as a biomonitoring organism and mollusk have become a popular choice for metal monitoring for several reasons (Hung et al. 2001). Bivalve accumulate measurable contaminant body burdens from environmental condition that are near or below the limit of detection in chemical analysis (Ullven 1993).The bivalves are sedentary, widespread and have a long life span, filter feeder, accumulate metals from food, water and also from the ingestion of inorganic particulate materials, hence fulfilling the criteria as good bioindicators (Huang et al. 2007).

Generally these indicators are able to evaluate the level of metal pollutants, but the problem of individual variability within and between sample batches still remains and this causes problems on the interpretation of the results. For this instance, body size or weight of the organism is one of the parameters that influence the uptake and bioaccumulation of the elements in the body. If the metal concentrations are expressed as concentration per unit body weight (µg/g), then one can expect the highest value to be recorded amongst the smallest individuals and could therefore render a misleading interpretation (Boyden 1974). Ibrahim and Mat (1995) shown that the total metal content is directly proportional to the body weight. The body burdens of metals in most bivalves have been used to identify and map areas with exceedingly high levels of trace metals and organic pollutants; hence they can be used as biomonitors for aquatic environment.

In order to use the bivalve as bioindicators in pollution-monitoring programmes, there is a need to develop a bioaccumulation database using various bivalve species. The data generated might be used in finding the most

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appropriate sentinel bivalve species for metal pollution monitoring programme for lentic and lotic ecosystems.

The objective of this study was to evaluate the potential of the fresh water bivalves, *Parreysia cylindrica, Parreysia corrugata* and *Corbicula striatella* to bioaccumulate the metals (Cu, Cd, Hg, As, Pb and Zn) in their soft tissues and to find suitable bivalve's species to use as sentinel animal for monitoring of metal pollution in the fresh water ecosystem.

Materials and Methods

Three species of fresh water bivalve, *Parreysia cylindrica, Parreysia corrugata* and *Corbicula striatella* were collected from various dams of Jalgaon, Nashik and Dhule districts of Maharashtra State, India. After collection animals were brought to laboratory and were cleaned and acclimatized in aquarium containing dechlorinated tap water for 10 days. During acclimatization and experimentation, the animals were fed with fresh water algae and water of aquarium was changed after every 24 h. Physico-chemical parameters of metal added water was estimated by method of APHA (1998).

After acclimatization, the active, medium, uniform size and healthy bivalves of each species were selected by measuring their shell length and width and divided into seven groups as below. Each species was separately exposed to fix average chronic concentration ($LC_{50/10}$) of each metal (Pb, As, Cd, Hg, Cu, and Zn) separately up to 30 days.

1st group was maintained as control
2nd group was exposed to chronic concentration (0.1719 ppm) of As for 30 days
3rd group was exposed to chronic concentration (0.23 ppm) of Cd for 30 days
4th group was exposed to chronic concentration (0.13 ppm) of Cu for 30 days
5th group was exposed to chronic concentration (0.06 ppm) of Hg for 30 days
6th group was exposed to chronic concentration (2.40 ppm) of Pb for 30 days
7th group was exposed to chronic concentration (5.1 ppm) of Zn for 30 days

The ten animals of each species from experimental and control groups were dissected on 10th day, 20th day and 30th day of exposure period and the whole body mass of each animal was dried in oven at 70–80°C. After oven drying dry weight of the whole body was measured.

500 mg dry powder of whole soft body tissue of control and experimental bivalves was digested in 10 ml of mixture of Nitric acid: Perchloric acid in (5:1) ratio. After half hours stirring the samples were kept overnight and on next day samples were digested on hot plate till the clear white fumes appeared. 10 ml volume of solution was maintained by adding acidic mixture of Nitric acid: Perchloric acid drop by drop. After allowing the flask to cool, double distilled water was added to bring the volume to 50 ml by using volumetric flask and then solution was filtered through Whatman filter paper number 41. From each sample, respective metal was analyzed by using Atomic Absorption Spectrophotometer (AAS).

Dry weight of each animal was used to calculate the metal body burden (μg/individual) and metal concentration per unit body weight (μg/g).

Results are expressed as mean ± standard deviation (SD). Difference among the means values of control and treatment were analyzed by Student's *t* test. Differences were considered statistically significant when, $p < 0.05$.

Results and Discussion

During the present investigation the physico-chemical parameters of metal added water were analyzed and are summarized in Table 1.

Table 1 Physico chemical parameters of tap water

Sr. no.	Sample	Parameters						
		pH	Temperature (°C)	Conductivity ($Ohm^{-1}cm^2\ mol^{-1}$)	Chlorides (mg/L)	Salinity (g/L)	Total alkalinity (mg/L)	Total hardness (mg/L)
1	Tap water	8.22 ± 0.62	25 ± 1.36	1.14 ± 0.40	78.95 ± 1.52	144.87 ± 3.81	378 ± 10.23	381.2 ± 8.25
2	$ZnSO_4$	8.35 ± 0.52	25 ± 1.36	1.08 ± 0.51	79.52 ± 1.01	145.91 ± 5.24	400 ± 9.54	383.2 ± 6.15
3	$CuSO_4$	8.46 ± 0.37	25 ± 1.36	1.09 ± 0.61	79.94 ± 1.15	146.70 ± 2.35	406.5 ± 8.57	383.2 ± 6.99
4	$PbNO_3$	8.33 ± 0.86	25 ± 1.36	1.12 ± 0.35	78.10 ± 1.01	143.31 ± 3.26	375 ± 7.65	384 ± 7.90
5	$CdCl_2$	8.34 ± 0.75	25 ± 1.36	1.12 ± 0.78	79.52 ± 1.15	145.91 ± 4.96	403 ± 9.10	382 ± 8.16
6	$HgCl_2$	8.54 ± 0.95	25 ± 1.36	1.11 ± 0.52	81.36 ± 1.68	149.29 ± 2.12	411.5 ± 7.12	384 ± 4.50
7	$AsHNa_2O_4$	8.46 ± 0.80	25 ± 1.36	1.11 ± 0.36	80.37 ± 1.59	147.47 ± 3.26	388 ± 7.12	386.6 ± 7.79

Table 2 Metal concentration and body burden in fresh water bivalve *Parreysia cylindrica* after exposure to average chronic concentrations of different metals

Sr. no.	Treatment	Exposure period 10 day			Exposure period 20 day			Exposure period 30 day		
		Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)	Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)	Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)
1	Control	0.57 ± 0.06	1518.6 ± 11.39	865.6 ± 11.82	0.51 ± 0.08	1477.2 ± 9.59	753.37 ± 8.74	0.38 ± 0.05	1095.4 ± 170.22	416 ± 6.25
2	$ZnSO_4$	$0.54^{NS} \pm 0.03$	$1853.3^{*} \pm 14.95$	$1001\ ^{*} \pm 14.65$	$0.54^{NS} \pm 0.01$	$1903.4^{NS} \pm 11.13$	$1028^{*} \pm 10.29$	$0.42^{NS} \pm 0.09$	$3538.6^{*} \pm 14.59$	$15.21^{NS} \pm 11.29$
3	Control	0.57 ± 0.06	1.11 ± 0.28	0.63 ± 0.06	0.51 ± 0.08	0.9 ± 0.11	0.46 ± 0.013	0.38 ± 0.05	0.71 ± 0.14	0.27 ± 0.016
4	$HgCl_2$	$0.60^{*} \pm 0.01$	$2.15^{NS} \pm 0.68$	$1.29^{NS} \pm 0.53$	$0.52^{NS} \pm 0.06$	$2.87^{NS} \pm 0.82$	$1.49^{NS} \pm 0.25$	$0.52^{*} \pm 0.1$	$3.96^{NS} \pm 0.77$	$2.06^{NS} \pm 0.93$
5	Control	0.65 ± 0.17	54.97 ± 1.69	35.73 ± 1.86	0.54 ± 0.03	54.28 ± 1.86	29.31 ± 1.85	0.41 ± 0.06	53.53 ± 2.27	21.87 ± 1.39
6	$PbNO_3$	$0.42^{*} \pm 0.11$	$195.27^{NS} \pm 2.32$	$82.01^{NS} \pm 2.94$	$0.43^{NS} \pm 0.09$	$231.49^{NS} \pm 2.14$	$99.54^{*} \pm 3.82$	$0.43^{*} \pm 0.03$	$267.01^{NS} \pm 1.91$	$114.81^{NS} \pm 2.41$
7	Control	0.65 ± 0.17	5.46 ± 1.13	3.55 ± 0.96	0.54 ± 0.03	4.8 ± 0.75	2.59 ± 0.45	0.41 ± 0.06	4.05 ± 1.34	1.66 ± 0.48
8	$CdCl_2$	$0.49^{NS} \pm 0.04$	$101^{NS} \pm 1.63$	$49.49^{NS} \pm 2.36$	$0.51^{NS} \pm 0.02$	$141.67^{*} \pm 2.24$	$72.25^{NS} \pm 0.73$	$0.51^{NS} \pm 0.02$	$182.62^{NS} \pm 1.91$	$93.14^{NS} \pm 0.56$
9	Control	0.65 ± 0.17	11.75 ± 1.40	7.64 ± 0.97	0.54 ± 0.03	8.43 ± 1.26	4.55 ± 0.57	0.41 ± 0.06	5.18 ± 1.29	2.12 ± 0.99
10	$CuSO_4$	$0.53^{NS} \pm 0.01$	$65.84^{NS} \pm 3.33$	$34.90^{NS} \pm 1.21$	$0.57^{NS} \pm 0.01$	$74.79^{NS} \pm 1.42$	$42.63^{NS} \pm 2.14$	$0.56^{NS} \pm 0.02$	$84.19^{*} \pm 1.81$	$47.15^{NS} \pm 2.89$
11	Control	0.65 ± 0.17	2.15 ± 0.79	1.40 ± 0.01	0.54 ± 0.03	1.75 ± 0.50	0.95 ± 0.26	0.41 ± 0.06	1.21 ± 0.4	0.50 ± 0.13
12	$AsHNa_2O_4$	$0.47^{*} \pm 0.01$	$10.24^{*} \pm 1.42$	$4.81^{NS} \pm 0.93$	$0.40^{NS} \pm 0.02$	$18.89^{NS} \pm 1.51$	$7.56^{NS} \pm 1.59$	$0.42^{*} \pm 0.03$	$33.12^{NS} \pm 1.611$	$13.91^{*} \pm 1.81$

* $p < 0.05$ (Significant *t* test), *NS* Not significant

Table 3 Metal concentration and body burden in fresh water bivalve *Corbicula striatella* after exposure to average chronic concentrations of different metals

Sr. no.	Treatment	Exposure period 10 day			Exposure period 20 day			Exposure period 30 day		
		Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)	Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)	Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)
1	Control	0.06 ± 0.02	817.7 ± 11.44	49.06 ± 4.15	0.06 ± 0.04	672.5 ± 9.05	40.35 ± 3.99	0.05 ± 0.01	447.4 ± 10.63	22.37 ± 2.91
2	$ZnSO_4$	$0.09^{NS} \pm 0.05$	$1232.2^{*} \pm 12.52$	$110.9^{NS} \pm 3.36$	0.07 ± 0.01	$1632.2^{*} \pm 13.25$	$114.25^{NS} \pm 5.36$	$0.07^{*} \pm 0.03$	$4139.2^{*} \pm 17.47$	$289.74^{*} \pm 5.25$
3	Control	0.06 ± 0.02	0.91 ± 0.15	0.05 ± 0.03	0.06 ± 0.04	0.88 ± 0.08	0.05 ± 0.01	0.05 ± 0.01	0.62 ± 0.12	0.03 ± 0.01
4	$HgCl_2$	$0.09^{*} \pm 0.01$	$1.59^{NS} \pm 0.77$	$0.14^{NS} \pm 0.02$	$0.07^{*} \pm 0.02$	$2.24^{NS} \pm 0.88$	$0.16^{NS} \pm 0.01$	$0.08^{NS} \pm 0.01$	$3.06^{NS} \pm 0.98$	$0.24^{NS} \pm 0.02$
5	Control	0.06 ± 0.02	116.6 ± 2.66	7 ± 0.17	0.06 ± 0.04	80.77 ± 1.7	4.85 ± 0.81	0.05 ± 0.01	62.15 ± 2.07	3.11 ± 0.86
6	$PbNO_3$	$0.08^{*} \pm 0.01$	$327.54^{*} \pm 2.16$	$26.20^{NS} \pm 1.28$	$0.08^{*} \pm 0.01$	$413.29^{*} \pm 1.96$	$33.06^{NS} \pm 2.4$	$0.06^{NS} \pm 0.02$	$729.6^{NS} \pm 2.43$	$43.8^{NS} \pm 1.37$
7	Control	0.06 ± 0.02	9 ± 1.64	0.54 ± 0.04	0.06 ± 0.04	7.02 ± 1.24	0.42 ± 0.05	0.05 ± 0.01	6.61 ± 1.43	0.33 ± 0.01
8	$CdCl_2$	$0.09^{NS} \pm 0.03$	$38.04^{NS} \pm 1.65$	$3.42^{NS} \pm 0.36$	$0.08^{NS} \pm 0.02$	$57.92^{NS} \pm 1.64$	$4.63^{NS} \pm 0.42$	0.06 ± 0.02	$69.9^{NS} \pm 2.16$	$4.19^{NS} \pm 0.38$
9	Control	0.06 ± 0.02	81.21 ± 1.72	4.87 ± 0.76	0.06 ± 0.04	79.44 ± 1.59	4.77 ± 0.72	0.05 ± 0.01	72.28 ± 1.92	3.61 ± 0.49
10	$CuSO_4$	$0.08^{NS} \pm 0.01$	$89.06^{NS} \pm 2.06$	$7.12^{NS} \pm 0.88$	$0.08^{*} \pm 0.01$	$99.8^{NS} \pm 1.83$	$7.98^{NS} \pm 0.1$	$0.08^{NS} \pm 0.02$	137.04 ± 1.89	$10.96^{*} \pm 0.98$
11	Control	0.06 ± 0.02	1.01 ± 0.43	0.06 ± 0.07	0.06 ± 0.04	0.78 ± 0.051	0.05 ± 0.01	0.05 ± 0.01	0.42 ± 0.014	0.02 ± 0.01
12	$AsHNa_2O_4$	$0.08^{*} \pm 0.01$	$6.04^{NS} \pm 1.74$	$0.48^{NS} \pm 0.13$	0.08 ± 0.01	$13.77^{NS} \pm 1.8$	$1.10^{NS} \pm 0.85$	$0.07^{*} \pm 0.01$	$28.23^{NS} \pm 1.79$	$1.98^{NS} \pm 0.52$

* $p < 0.05$ (Significant *t* test), *NS* Not significant

The patterns of accumulation of metal studied comparatively in three fresh water species of bivalves exposed to fix average chronic concentration of six metals (As, Cd, Cu, Hg, Pb and Zn) separately and result are summarized in Tables 2, 3, 4. The data revealed a significant increase in metal concentration and total body burden levels in the whole soft body tissues of experimental bivalves with increase in exposure period as compared to the bivalve maintained as control. In the present investigation it was observed that different species of bivalve's shows different uptake pattern for different metals. It was observed that Zn, Pb, and Cu concentration and their metal body burden were highest in the *Corbicula striatella,* Hg and As was highest in *Parreysia corrugata* and Cd was highest in *Parreysia cylindrica.*

The observed differences in tissue metal concentration and body burden between bivalve species might be due to variation in body size and weight. Variability between closely related species was reflected by different uptake rates and different physiological rates such as pumping, filtration and respiration. These qualities are specific for different species. Different species of bivalve have different metabolic rate that might be responsible for observed variation. Interaction of metals in body tissues seems to vary from species to species. At the same time the attitude of the organism is specific for different element and substance.

The interspecific difference in the metal concentrations was evidenced that different organisms display a range of capacities from low accumulation of certain elements to very high accumulation (Paez-Osuna et al. 2000). Element concentrations in molluscs differ between different species (Lacastesantos-Fernandez 2004) due to species-specific ability/capacity to regulate or accumulate trace metals (Otchere et al. 2003). The inter-specific difference of metal assimilation efficiencies might be related to the species-specific digestive physiology and absorption rate of a metal across gut epithelium (Lee and Lee 2005).

Metal concentration in soft bodies has been discussed in all research concerned. Pillai et al. (1986) estimated the metal load in clams, *Vellorita cyprinoides*, *Meretrix costa, Crassostrea madrasensis*, *Perna viridis* and *Perna indica* and found significant variations in the concentrations of iron, zinc, copper, lead, cadmium, nickel and cobalt. Of the bivalves, clams showed high concentration levels of all metals especially, iron and zinc. Jasmine et al. (1987) found that small oysters contained significantly higher mercury content than larger ones. According to the Gundacker (1999), a zebra mussel accumulates high amounts of potentially toxic metals and was widely used as a biomonitoring organism. Avelar et al. (2000) reported that Oyster and mussels can accumulate Cd in their tissues at levels up to 100,000 times higher than the levels observed in the water in which they live. Bioaccumulation of some

Table 4 Metal concentration and body burden in fresh water bivalve *Parreysia corrugata* after exposure to average chronic concentrations of different metals

Sr. no.	Treatment	Exposure period 10 day			Exposure period 20 day			Exposure period 30 day		
		Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)	Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)	Body dry wt. (gm)	Metal conc. (µg/gm)	Metal body burden (µg/individual)
1	Control	0.43 ± 0.05	884 ± 8.02	380.12 ± 6.19	0.33 ± 0.02	734.1 ± 7.06	242.25 ± 6.88	0.40 ± 0.02	719 ± 8.64	287.6 ± 6.33
2	$ZnSO_4$	$0.52^{NS} \pm 0.02$	$1256.5^{*} \pm 17$	$653.38^{NS} \pm 6.42$	$0.46^{*} \pm 0.02$	$2521^{*} \pm 15.66$	$1159.61^{*} \pm 13$	$0.34^{NS} \pm 0.03$	$3182.5^{*} \pm 15$	$102.05^{*} \pm 11.06$
3	Control	0.33 ± 0.02	1.25 ± 0.28	0.41 ± 0.01	0.38 ± 0.09	1.09 ± 0.28	0.41 ± 0.01	0.36 ± 0.02	0.88 ± 0.08	0.32 ± 0.02
4	$HgCl_2$	$0.43^{NS} \pm 0.01$	$2.35^{NS} \pm 0.80$	$1.01^{NS} \pm 0.28$	$0.40^{NS} \pm 0.02$	$2.95^{NS} \pm 0.94$	$1.18^{NS} \pm 0.47$	$0.40^{NS} \pm 0.02$	$4.12^{NS} \pm 1.09$	$1.65^{NS} \pm 0.46$
5	Control	0.43 ± 0.05	79.58 ± 2.22	34.21 ± 1.22	0.33 ± 0.02	39.33 ± 1.72	12.98 ± 1.87	0.40 ± 0.02	12.5 ± 1.1	5 ± 0.97
6	$PbNO_3$	$0.46^{NS} \pm 0.02$	$168.75^{*} \pm 19$	$77.61^{NS} \pm 2.04$	$0.44^{NS} \pm 0.02$	$400.02^{NS} \pm 19$	$176.01^{NS} \pm 3.97$	$0.43^{*} \pm 0.02$	$602.01^{*} \pm 131.79$	$258.86^{NS} \pm 3.02$
7	Control	0.56 ± 0.02	8.51 ± 1.25	4.77 ± 1.25	0.50 ± 0.01	7.53 ± 1.54	3.77 ± 1.28	0.54 ± 0.01	6.55 ± 1.04	3.54 ± 0.51
8	$CdCl_2$	$0.52^{*} \pm 0.05$	$69.39^{NS} \pm 2.1$	$36.08^{NS} \pm 2.38$	$0.66^{NS} \pm 0.01$	$95.74^{NS} \pm 1.87$	$63.19^{*} \pm 2.47$	$0.53^{NS} \pm 0.05$	$121.01^{NS} \pm 1.74$	$64.14^{NS} \pm 2.53$
9	Control	0.43 ± 0.05	9.05 ± 0.47	3.89 ± 0.96	0.33 ± 0.02	8.22 ± 0.46	2.71 ± 0.77	0.40 ± 0.02	7.37 ± 0.49	2.95 ± 0.94
10	$CuSO_4$	$0.54^{NS} \pm 0.02$	$42.12^{NS} \pm 1.96$	$22.74^{NS} \pm 1.75$	$0.41^{NS} \pm 0.03$	$77.87^{NS} \pm 1.36$	$31.93^{*} \pm 1.47$	$0.34^{NS} \pm 0.02$	$83.97^{NS} \pm 1.42$	$28.55^{NS} \pm 2.54$
11	Control	0.43 ± 0.05	2.27 ± 0.48	0.98 ± 0.09	0.33 ± 0.02	1.95 ± 0.49	0.64 ± 0.06	0.40 ± 0.02	1.48 ± 0.48	0.59 ± 0.03
12	$AsHNa_2O_4$	$0.45^{*} \pm 0.03$	$11.07^{NS} \pm 1.07$	$4.98^{NS} \pm 0.47$	$0.31^{NS} \pm 0.02$	$21.12^{NS} \pm 1.39$	$6.55^{NS} \pm 0.95$	0.35 ± 0.02	$34.05^{NS} \pm 1.88$	$11.92^{NS} \pm 0.92$

* $p < 0.05$ (Significant *t* test), *NS* Not significant

metals (Cd, Fe, Zn, and Ca) in two bivalve species was studied by Goksu et al. (2005).

In the present study it was observed that Zn, Pb, and Cu concentration and metal body burden was highest in the *Corbicula striatella,* Hg and As was highest in *Parreysia corrugata* and Cd was highest in *Parreysia cylindrica.* Therefore, *Corbicula striatella* is being proposed as sentinel organism for monitoring of Zn, Pb, and Cu*, Parreysia corrugata* for Hg and As and *Parreysia cylindrica* for Cd in fresh water ecosystem.

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