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Bio-Accumulation of Heavy Metals in Some Aquatic Species Collected in the Jamshedpur Stretch of Kharkai River of Chotanagpur Plateau, India

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ABSTRACT

Bio-accumulation of some heavy metals has been observed in *Lepidocephalichthyes guntea* (Local name : Gunthi), *Palaemon malcolmsoni* (Local name : Jhinga, Chingri) and *Thiara sp.* (snail) collected in the Jamshedpur stretch of Kharkai river of Chotanagpur plateau, India. Kharkai, which is a principal tributary of Subarnarekha river, encircles, the entire industrial belt of Jamshedpur township. The concentration of heavy metals in the river water, riverbed soil and aquatic species obtained therein point towards the accumulation of these metals in soil as well as living organisms. These findings clearly demonstrate the fact that Kharkai is a metal polluted river and underscores the need to take immediate abatement measures.

***Key words :** Bio-accumulation, Heavy metal, Kharkai river, Aquatic species*

Introduction

Kharkai river is the principal tributary of Subarnarekha river. The river is formed by the union of two hill streams, Terlo and Koranjai at Seraikela near Jamshedpur. The length of Kharkai proper is about 80 km and it is fed by several smaller streams. Kharkai encircles entire industrial belt of Jamshedpur township before meeting Subarnarekha at rivers' meet point at Sonari in Jamshedpur. Several industries, small and big down the course of the river discharge their effluents in it without proper and adequate treatment.

A large number of local fishermen depend on this river for their livelihood. The catches directly go to the local market and are consumed by the local people. The industrial pollution of this river has a visible effect which is evident from the dwindling number of catches, depleted oxygen level, fluctuating pH etc. However, till date, no systematic study has been carried out to assess the extent of pollution of Kharkai and Subarnarekha rivers and its impact on the eco-system of these rivers. This communication is a part of such a study, recently being carried out any National Metallurgical Laboratory, Jamshedpur, India. The objective of this work is to ascertain the level of pollution in the Kharkai river by measuring heavy metal contents in the river water, riverbed soil and some of the aquatic species obtained therein. All the samples were collected from the Jamshedpur stretch of Kharkai river.

Accumulation of heavy metals in aquatic species is a widely studied subject. Majority of them are, however, fundamental studies carried out under laboratory conditions. Metals are necessary for the normal and healthy physiological functions in mammals but only in trace quantity. These include, Cu, Fe, Zn, Mn, Co, Se and Cr (Harper *et al.*, 1977). It may be safely assumed that most of these, if not all, have similar functions in

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fish though the optimum concentrations are largely unknown (Heath, 1987). A nutrient element turns into a toxic one if its concentration exceeds a certain tolerance limit, which not only disturbs the fish physiology but also makes them toxic for human consumption. As an example, Cu is required in ultra trace quantity in freshwater fish for their growth and development but it is highly toxic even at fairly low concentration and may result in death or sublethal pathology at different functional systems (Moore and Rmamoorthy, 1984). Gill histopathology has been reported due to the presence of Cu (Baker, 1969), Hg (Olson *et al.*, 1974), Ni (Hughes *et al.*, 1979), Zn (Skidmore and Tovell, 1972). As (Sorensen *et al.*, 1979) and Cd (Stromberg *et al.*, 1983). Anemia has been reported due to Cd in flounder (Johansson-Sjobeck and Larson, 1978), lead in trout (Johansson-Sjobeck and Larson, 1979), Hg in bass (Dawson, 1982), Zn in gourmai (Mishra and Srivastava, 1979). Increase in hematocrit and haemoglobin concentration has been reported in trout due to 38 ppb of Cu in 6-330 days (McKim *et al.*, 1970) and 1-50 ppm of Cr in 4 days (van der Putte *et al.*, 1982).

Studies on heavy metal pollution under real conditions are relatively few in number. To the best of our knowledge, no such study has been reported on the Kharkai river. Present group of authors have recently communicated a bio-accumulation study of some of the heavy metals observed in the *Barilius bendelisis* collected from Kharkai (Sinha *et al.*, 1997).

Materials and Methods

Collection of samples

L. guntea, P. malcolmsoni and Thiara sp. were captured from Kharkai river at the Sonari rivers' meet point, Jamshedpur in the month of November 1996. *P. malcolmsoni* was analysed as whole because of its small size. Also, because of the small size all the organs of *L. guntea* could not be analysed. Only the head and remaining part of the body were separated and analysed separately. Hard and soft tissues of the *Thiara* snail were separated and analysed for their metal contents. The mud adhered to the walls of the snail species were scraped and analysed as an independent sample which revealed some very useful information. This sample will be referred to as 'mud thiara' in our subsequent discussion. In addition to the living organisms, riverbed soil was collected from two different sections of the river, one from a depth inside and other near the shore. They have been named as deep riverbed soil' and 'shore riverbed soil' respectively.

Dissolution of fish samples

The samples were air dried and an accurate weight was digested with 10 ml of HCl, 5ml of HNO_3 for about 2 hours at low heat till the organic matter was completely decomposed. 10 ml of perchloric acid was added to it and the sample was heated to dense white fuming. The sample was further digested with 5 ml of HCl and 20 ml of distilled water for half an hour at low heat. The solution was cooled and the final volume was made upto 50 ml.

Dissolution of soil samples

About 1 g of the sample was taken and digested with the tri acid mixture in the same way as fish samples. After perchloric furming and digestion with HCl and water for half an hour, the resulting solution was filtered. The filtrate was retained and the residue was heated with HF for removing silica. Complete removal of silica was followed by fusing the residue with potassium pyrosulphate and taking the melt in dilute HCl solution. The digest was mixed with the earlier filtrate and the total volume was made upto 100 ml.

Water sample

One litre of the river water sample was stabilised with HNO_3 and reduced to 50 ml by boiling. The boiling generated some macro solid particulate matters which were filtered, digested in acid mixture and taken separately in the solution.

Equipment

Cu, Co, Ni, Fe, Mn, Zn and Cr were estimated by GBC 908 AA atomic absorption spectrometer, Pb, V, As, Cd, Sb and Bi were analysed by Shimadzu ICPS 1000 III optical emission spectrometer.

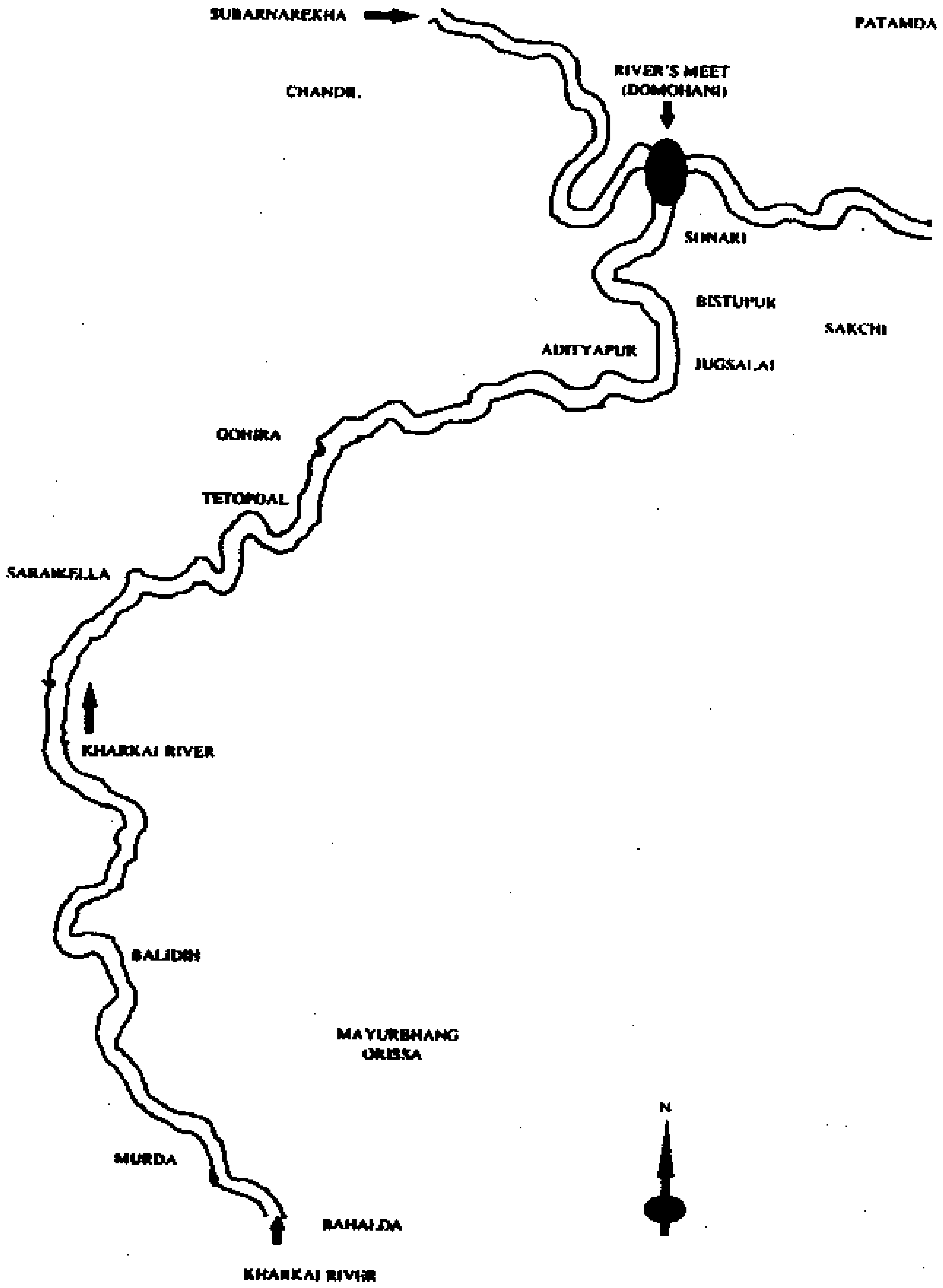

Fig. 1. Course of Kharkai River

Reagents

Potassium pyrosulphate and all acids used were of AR grade. 18 MΩ ASTM grade 1 water was used for making the solutions.

Results and Discussion

Figure 1 shows the course of Kharkai river and its meeting point with Subarnarekha. Also indicated in Figure 1 is the collection site for the samples studied in this work.

Table 1 lists the bio-concentrations of Fe, Mn, Zn, Cu, Co, Ni, Pb, Cr, V, As, Sb, Cd and Bi in mg/kg in all the samples studied in the present work, 'n.f.' in Table 1 stands for 'not found'. Table 2 gives the bio-accumulation factors (BAF) for those metals for which the factor could be calculated. Quite expectedly, the BAF varied from organ to organ. Bio-accumulation factor (BAF) for a metal X in a sample Y is defined as,

$$\mathrm{BAF} = \frac{\text{Concentration of metal X in Y (mg/kg)}}{\text{Concentration of metal X in river water (mg/lg)}} \qquad (1)$$

BAF is an indicator of how much a sample has accumulated a particular metal from the river water which is the primary source. Quite naturally, if a metal is not traceable in the river water, BAF can not be calculated for that metal even if the metal is detectable in the sample. The zero denominator makes the factor indeterminate. However, BAF in such cases may be found out by taking recourse to a more sensitive technique.

It may be seen from Table 1 that in living species, iron accumulation occurs in descending order in the soft part of *thiara* sp. followed by *P. malcolmsoni* and hard part thiara *sp.* Iron is evenly distributed in the head and body of *L. guntea.* Expectedly, both types of riverbed soil show high iron concentration. However, most interestingly, the mud *thiara* shows higher iron concentration than the riverbed soil. As the river water does not show any appreciable iron concentration, this clearly indicates that most of the iron content of water has either been deposited on the soil and/or has been absorbed by the living organisms. This is also reflected in Table 2 of bio-accumulation factors. All the living species considered in the present work are iron resistant. Especially, soft part of *thiara* accumulates iron to a very large extent. Hard part of *thiara*, which is essentially a calcium shell, accumulates relatively less iron. Very high concentration of iron in the mud adhered to the walls of the *thiara* sp. is most interesting as it points towards certain biological mechanism which binds iron atoms at the shell walls. This point will be addressed in more detail in relation to other metals also in later part of our discussion.

Zinc accumulation occurs in the order Head *L. guntea* > S. part *thiara* > *P. malcolmsoni* > Body *L. guntea* > H. part *thiara*, thus showing greatest resistance of *L. guntea* towards Zn. In fact, Zn accumulation factor of *L. guntea* is even higher than its Fe accumulation factor, thus showing a special affinity of this species towards Zn. In an earlier study (Sinha *et al.*, 1997), a similar situation was also observed in the gill of *B. bendelisis* captured from Kharkai river. Deep riverbed soil has a higher Zn accumulation factor compared to the shore riverbed soil. It is interesting to note that Head *L. guntea* shows even a higher Zn accumulation factor than the deep riverbed soil. Once again mud *thiara* has the highest Zn accumulation factor, much higher than the deep riverbed soil.

Abruptly high concentration of lead is observed in the head of *L. Guntea,* while in other samples, except mud thaira, lead is observed in much lower concentration. Hard and soft part of *thiara* show practically no lead concentration. Mud *thiara,* however, shows remarkably high Pb concentration, thus strengthening our earlier assertion that cell walls of *thiara* has a biological protection mechanism by which it does not allow the toxic elements to enter inside the cells. Further evidence to this assertion will be furnished in the later part of our discussion. High value of Pb in the head of *L. guntea* is a pointer towards the accumulation of lead in the head portion by some specific mechanism. Any further comment on this warrants elaborate study, which however, is beyond the scope of this work. However, it may be recommended from the present study that head of *L. guntea* is not an edible part and must be rejected while processing.

P. malcolmsoni records maximum Cu concentration which is a very typical phenomenon. How and why this occurs is once again a subject of further research. Like other metals as observed so far, soft part *thiara* shows higher Cu concentration than the hard part while expectedly, mud thiara shows much higher Cu concentration, almost as high as *P. malcolmsoni.* Interestingly, there is a difference in the Cu deposition on the deep and shore riverbed soil.

BAF for Mn is generally high in all the samples studied. But it is remarkably high in mud *thiara* followed by hard part *thiara*. In mud *thiara* it is more than three times of hard part *thiara*. Riverbed soil also shows appreciable Mn deposition. The river water, however, registers very little Mn concentration thus indicating very quick biosorption and/or chemical deposition of Mn. It is also very interesting to note that for almost all the metals, soft part *thiara* shows higher value than the hard part except for Mn, where hard part shows relatively higher Mn concentration.

Mud *thiara* and both deep and shore riverbed soil recorded appreciable concentration of Cr. However, it could not be detected in the river water. Hence, the BAFs for Cr could not be calculated. Except for shore riverbed soil. So could not be detected in any of the samples studied.

Table 1 also lists chemical analyses of a number additional toxic elements for the same set of samples. These include V, As, Cd, Sb and Bi. Noticeable amount of V has been observed in mud *thiara* and riverbed soils with mud *thiara* being the highest. Most alarming situation has been observed for As. Mud *thiara* and riverbed soils show extremely high deposition of As. As in traces has also been found in *L. guntea, P. malcolmsoni* and hard part *thiara*. Soft part *thiara* does not show any trace of As. Cd level, though detectable, is generally low. Even for Cd, mud *thiara* shows maximum deposition. Most unexpectedly, soft part *thiara* shows detectable concentration of Sb, while hard part shows none. For Bi, one observes appreciable deposition of Bi in mud *thiara* and riverbed soils. In all these toxic elements, only the presence As and Bi could be detected in the river water though they are

Table 1. Metal contents (mg/kg) of Kharkai river water, riverbed soil and different aquatic species captured therefrom

Sample	Fe	Ni	Zn	Pb	Cu	Mn	Cr	Co	V	As	Cd	Sb	Bi
Head *L. guntea*	50	n.f	60	28	4	10	n.f	n.f	0.74	1.2	0.18	3.7	0.55
Body *L. guntea*	40	n.f	23	2.7	1	7	n.f	n.f	n.f	1.3	n.f	0.87	0.58
P. malcolmsoni	150	n.f	31	3.3	25	8	3.8	n.f	n.f	3.3	n.f	0.65	0.33
Hard part *thiara*	76	0.3	14	n.f	2	349	5	n.f	n.f	0.45	0.09	1.2	3.1
Soft part *thiara*	480	n.f	40	n.f	10	170	10	n.f	n.f	n.f	0.10	14.4	1.04
Mud *thiara*	10800	200	140	90	23	1310	65	n.f	22	110	2.4	n.f	46
Deep riverbed soil	9200	90	41	n.f	14	220	90	n.f	14	51	1.1	n.f	33
Shore riverbed soil	8400	10	7	3	4.2	250	90	5	19	42	0.44	0.4	60
River water	0.064	n.f	0.016	0.016	0.031	0.024	n.f	n.f	n.f	0.06	n.f	n.f	0.02

Table 2. Bio-accumulation factor (BAF) of different metals in different aquatic species of Kharkai river

Specimen	Fe x 10^5	Zn x 10^3	Pb x 10^3	Cu x 10^3	As x 10^3	Bi x 10^3
Head *L. guntea*	0.008	3.75	1.75	0.13	0.02	0.03
Body *L. guntea*	0.006	1.44	0.17	0.03	0.02	0.03
P. malcolmsoni	0.023	1.94	0.21	0.81	0.05	0.02
Hard part *thiara*	0.012	0.87	0	0.06	0.07	0.01
Soft part *thiara*	0.075	2.5	0	0.32	0	0.05
Mud *thiara*	1.69	8.75	5.62	0.74	1.83	2.3
Deep riverbed soil	1.44	2.56	0	0.45	0.85	1.65
Shore riverbed soil	1.31	0.44	0.19	0.13	0.70	3.00

reasonably below the safety limits. This, however, does not portray the true pollution status of river Kharkai. As already mentioned, toxic elements discharged in the river through different routes are either biosorped by the living organisms or chemically deposited on the riverbed soil which is evident from the data furnished.

In all the thirteen elements studied in the present work, except for Co and Sb, all the remaining elements show high degree of accumulation in mud *thiara.* Barring Cr and Cu, the accumulation, in fact, is highest for mud thiara. At the same time, except for Sb, soft and hard part thiara show relatively much less accumulation for metals like Fe, Ni, Zn, Pb, Cu, Mn and Cr. In toxic group of metals, the accumulation in the soft and hard part is even lesser. This is also an established fact that *thiara* sp. have the capability to survive and multiple in metal polluted environments. All these facts put together very strongly point towards a very striking phenomenon. In all possibility, *thiara* species must be having some inherent protection mechanism by which they can generate some chelating reagent outside the walls which binds the metals that come in contact and thus protect the organism from being either overloaded or toxicated.

It has been observed during our discussion that *L. guntea* is extremely resistant towards Zn. In an earlier study, present group of authors noted a similar situation in *Barilius bendelisis* specimen captured from the same river. Different visceral organs of *B. bendelisis,* especially gill, showed very high Zn resistance. Though different organs of *L. guntea* were not studied in the present work due to small size of the specimen, nevertheless, Zn accumulation factor of *L. guntea* (3750) compared well with the Zn accumulation factor of gill *B. bendelisis* (4375). Thus, it is recommended that *L. guntea* is a bio indicator of Zn and it is not edible if captured from a water body polluted with Zn.

It has already been mentioned that metals carried by the water are either biosorped by the algae and planktons or they quickly get chemically deposited on the riverbed. The pH of the river Kharkai has been found to vary between 6.7 to 7.3. The solubility product of hydroxides of almost all the metals studied in the present work are very low. The observed pH is sufficient enough for the formation of these hydroxides and subsequent deposition on the riverbed soil. As the fish snail and prawns considered in the present study primarily feed on these algae and plankton, the metals might have entered their body through the food route. Some of them however, might have entered through drinking water as well.

Conclusion

Present study concludes the following

All the species considered in the present study, namely, *L. guntea, P. malcolmsoni* and *thiara* snail species are iron resistant. Especially, soft part of *thiara* accumulates iron to a large extent. Abruptly high concentration of lead is observed in the head of *L. guntea*

P. malcolmsoni records maximum Cu concentration of all the species studied.

Almost all the metals studied in this work have been found in appreciable concentration in the riverbed soil whereas many of them were not found even in detectable concentration in the river water. This indicates that these metals are either biosorped by the living aquatic species or they are chemically deposited on the riverbed soil.

Mud adhered to the *thiara* is found to be richest in al the metals. This is notwithstanding the fact that the soft part of *thiara* does not show detectable amount of many of the toxic elements. This indicates that there exists an inherent biological protection mechanism by which the toxic elements are denied entry into the inside of *thiara*. This also explains the apparent resistance of thiara towards metal polluted water bodies.

Pb, As and Bi have been detected in the river water and found in reasonably high concentration in the riverbed soil and aquatic species of Kharkai river. V and Sb, though not detected in the water have been found in the riverbed soil and aquatic species. These, in addition to Fe, Zn, Mn and Cu point towards the metal load of this river. The situation demands immediate and sincere attention to this problem and an urgent assessment of the entire eco system of Kharkai and Subarnarekha river with special reference to heavy metal pollution.

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