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Studies on Metal Contamination Levels in Plankton and Their Role as Biological Indicator of Water Pollution in the River Ravi

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Abstract: The fate of plankton as biological indicator of metal's pollution in the stretch of river Ravi from Baloki headworks to Sidhnai barrage has been studied. This investigation reveals that effluents from three main tributaries viz. Degh nulla, Sammundri and Sukhrawa main drains have adversely affected the planktonic biota in the river. Among the three tributaries, Degh nulla exhibited significantly higher contaminated plankton, showing the reason due to uptake and accumulation of heavy metals from water and sediments. This caused significant impact of metallic ions in water body on its accumulation in plankton. Therefore, in an aquatic ecosystem plankton showed a great tendency to accumulate metals in their bodies from water and sediments. Among phytoplankton, *Aphanocapsa*, *Bumilleria*, *Bacillaria*, *Cladophora*, *Closterium*, *Cocconeis*, *Cosmarium*, *Eudorina*, *Microcystis*, *Oscillatoria*, *Pandorina*, *Scenadesmus*, *Spyrogyra*, *Volvox* and *Zygnema* indicated direct relationships with the intensity of pollution as these genera were almost absent in highly polluted tributaries. However, the genera viz. *Aphanothece*, *Anabaena*, *Arthrospira*, *Cyclotella*, *Denticulla*, *Dinobryon*, *Euglena*, *Navicula*, *Peridinium*, *Phacus* and *Synedra* showed considerable tolerance against heavy metals pollution. Among the zooplankton, *Asplanchna*, *Brachionus*, *Canthocamptus*, *Cyclops*, *Diaptomus*, *Moina* and *Polyarthra* were almost absent at highly polluted sites. The genera viz. *Bosmina*, *Filinia*, *Keratella* and *Monnstyla* showed considerable tolerance against metallic ion pollution. *Daphnia* appeared to be a sensitive form against metallic pollution in water. Therefore, present investigation reveals that plankton are the best indicators of metal pollution in the river Ravi aquatic habitat.

Key words: River Ravi, metal pollution, plankton, biological indicator

INTRODUCTION

In the aquatic habitats, heavy metals may enter fish bodies in three possible ways: through the body surface, the gills or the digestive tract (Pourang, 1995). Fish gills are regarded as the important site for direct uptake from the water (Thomas *et al*., 2003), whereas the body surface is generally assumed to play a minor role in heavy metal uptake in fish (Dallinger *et al*., 1987). Food in the form of plankton are also an important source for heavy metal enrichment in fish body (Novelli *et al*., 1998), potentially leading to bio-magnification, the increase of pollutants up the food chain (Nogami *et al*., 2000). The toxic effects of metals on aquatic ecosystems ranged from a complete loss of biota to subtle effects on rates of reproduction, growth and mortality of organisms (Hodson and Spargue, 1998). Metals are readily dissolved and transported in water and aquatic biota are, therefore, prone to their adverse effects.

As a result of rapid industrialization in Pakistan, the toxic heavy metals are continuously released into the rivers. Therefore, metals are the problem of magnitude and of ecological significance due to their high toxicity and ability to accumulate in living organisms. Residues of contaminants in biota are often used to assess environmental quality. Measurements in biota may supplement measurements in the physical environment. To provide a more comprehensive insight into the extent of metal contamination, it will be of substantial use to connect information on the spatial distribution of metals in the physical environment (i.e., sediment and water) with information from a biological matrix (i.e. plankton and fish) in a defined spatial scale. In aquatic ecosystems, heavy metals have received considerable attention due to their toxicity and accumulation in biota (Mason, 1991). Some of these elements are toxic to living organisms even at quite low concentrations, whereas others are biologically essential and natural constituents of the aquatic ecosystems and only become toxic at very high concentrations. Studies have demonstrated that the determination of metal concentrations in suspended matters and plankton are more sensitive than the dissolved concentrations when used as indicators of contamination in hydrologic systems (Luoma, 1990).

However, total metal concentrations in sediments do not necessarily reflect concentrations that are available to biota. Aquatic organisms have been used in comparative monitoring of pollution effects in different systems and to locate sources of toxicants (Phillip, 2002). Bio-monitoring approach has proved to be promising as a reliable means of quantifying biological effects of complex effluents. River Ravi originates from India and enters Pakistan near village Tadyal, Kot Naina, Tehsil Shakargarh. This river flows down about 560 km to join river Chenab near village Sayyal Faqir, Sidhnai, Tehsil Kabirwala. In addition to surface run-off up-stream water, it receives water from link canals also. The river Ravi stretch, from Baloki headworks to Sidhnai barrage, was investigated for metals toxicity of plankton which are the main food items of indigenous fish species viz. *Catla catla, Labeo rohita* and *Cirrhina mrigala* that are on the verge of extinction due to heavy metal enrichment of aquatic ecosystem.

MATERIALS AND METHODS

Sapling stations were fixed at five river sites viz. Baloki headworks, Syedwala, Maripattan bridge, Kamalia-Chichawatni (K.C. bridge) and Sidhnai barrage and at three main effluent discharging tributaries viz. Degh nulla (Drain), Sammundri and Sukhrawa main drains. Plankton samples, from these stations were collected on fortnightly basis by filtering nearly 50-60 L of water through plankton net with a pore width of about 10 micrometer. The frequency and percentage of different groups and different species of algae were determined (Venkateswarlu, 1969; Boyd, 1995). In case of benthic algae, number of individuals were examined to calculate the density of different groups. Metals viz. iron, zinc, lead, nickel and manganese concentrations in the plankton samples (dry basis) were determined on fortnightly basis (Anonymous, 1989). Data were analyzed by using analysis of variance and Duncan's Multiple Range tests (Steel and Torrie, 1986). MSTAT-C package of the computer was used for the analyses of data.

RESULTS

Iron: Iron in plankton samples fluctuated significantly among all the river site and tributary sampling stations. Baloki headworks showed significantly highest planktonic mean contamination level of 12818.03±8996.07 $\mu g\ g^{-1}$ while the same was minimum (5154.06±2972.86 $\mu g\ g^{-1}$) at Syedwala. The plankton at Sammundri main drain were highly contaminated with iron (16849.91±4554.92 $\mu g\ g^{-1}$), followed by the contamination levels of 10441.37±5239.08 and 4575.77±1776.22 $\mu g\ g^{-1}$ at Degh nulla and Sukhrawa main drain, respectively (Table 1).

Zinc: Highly significant differences existed both among river sites and effluent discharging tributaries for zinc contamination in plankton samples. In the river course, the plankton at Syedwala had the mean highest zinc contamination of 290.13±117.70 $\mu g\ g^{-1}$ while the same was minimum at Baloki headworks (235.17±99.35 $\mu g\ g^{-1}$). All the three effluent discharging tributaries showed significantly higher zinc contaminated plankton than the samples collected from the river stretch. The plankton in Sammundri main drain showed significantly higher zinc than that in Sukhrawa main drain and Degh nulla. However, the differences among all the three tributaries, for zinc contamination levels, were statistically significant (Table 1).

Lead: Accumulation of lead in plankton samples collected from all river site stations and three tributaries varied significantly. Among the river site sampling stations, Maripattan bridge exhibited the highest mean lead contamination level of 43.61±20.65 $\mu g\ g^{-1}$, followed by that of 35.98±19.27, 34.57±18.01, 32.05±13.35 and 30.15±9.16 $\mu g\ g^{-1}$ at Baloki headworks, Syed wala, K.C. bridge and Sidhnai barrage, respectively. The plankton at Degh nulla showed significantly higher lead contamination of 41.54±39.08 $\mu g\ g^{-1}$, followed by that in Sukhrawa and Sammundri main drains with the mean lead concentration of 33.30±27.72 and 24.09±15.22 $\mu g\ g^{-1}$, respectively (Table 1).

Nickel: Table 1 shows highly significant differences among sampling stations for the nickel contaminations in plankton. Regarding river site sampling stations, the plankton collected from Maripattan bridge had the mean highest nickel contamination of 63.69±43.99 $\mu g\ g^{-1}$ while the same was minimum as 54.88±34.16 $\mu g\ g^{-1}$ at Syedwala. Degh nulla contributed significantly higher nickel toxicity towards planktonic productivity (76.03±62.30 $\mu g\ g^{-1}$), followed by the contamination levels of 63.76±26.74 and 39.47±24.62 $\mu g\ g^{-1}$ observed at Sukhrawa and Sammundri main drains, respectively. The toxicity levels of nickel in the plankton samples collected from all the three effluent discharging tributaries varied significantly.

Manganese: The plankton collected from river site sampling stations showed significant variations for manganese contaminations. The plankton at Sidhnai barrage had the mean highest manganese (530.95±271.02 $\mu g\ g^{-1}$) while the lowest concentration was observed at Syedwala as 512.09±275.59 $\mu g\ g^{-1}$. However, there were non-significant differences between Baloki headworks and Syedwala and, among Maripattan bridge, K.C. bridge and Sidhnai barrage. Among the three effluent discharging tributaries, the plankton in Degh nulla

Table 1: Metals toxicity of plankton, determined on dry weight basis, (µg g^{-1} ± SD) collected from the river Ravi and related effluent discharging tributaries

Sampling station	Iron	Zinc	Lead	Nickel	Manganese
River sites					
Baloki headworks	12818.03±996.07a	235.17±99.35c	35.98±19.27b	57.16±38.86c	516.08±244.67c
Syedwala	5154.06±2972.86e	290.13±117.70ab	34.57±18.01b	54.88±34.16d	512.09±275.59c
Maripattan bridge	6309.96±2540.54d	275.93±159.89b	43.61±20.65a	63.69±43.99a	527.91±371.80ab
K.C. bridge	7229.46±2230.96c	287.76±130.81ab	32.05±13.35bc	61.42±21.28b	525.99 ± 264.37b
Sidhnai Barrage	9122.42±3718.60b	265.20±106.03bc	30.15±9.16d	60.26±28.99b	530.95±271.02ab
Effluent discharging tributaries					
Degh nulla	10441.37±5239.08c	317.15±172.37c	41.54±39.08a	76.03±62.30a	589.74±275.91a
Sammundri main drain	16849.91±4554.92a	610.49±229.31a	24.09±15.22c	39.47±24.62c	534.62±158.51b
Sukhrawa main drain	4575.77±1776.22b	393.50±135.62b	33.30±27.72b	63.76±26.74b	372.80±197.53c

(Means with similar letters in a single column are statistically similar at p<0.05)

Table 2: Planktonic productivity indices (individuals per liter of water) of the river Ravi stretch and effluent discharging tributaries

	River site sampling stations					Effluent discharging tributaries		
Plankton	Baloki headworks	Syedwala	Maripattan	K. C. bridge	Sidhnai barrage	Degh nulla (Drain)	Sammundri main drain	Sukhrawa main drain
Phytoplankton								
Aphanothece	110±180.09	167±105.87	105 ± 99.34	40±42.83	190±129.00	12±22.43	13±26.91	8±29.00
Anabaena	28±66.90	45±39.99	101±65.23	65±101.45	39±30.56	9±27.23	22±44.44	16±25.23
Aphanocapsa	122±160.00	167±98.56	47±43.21	22±45.92	11±50.22	-	-	-
Arthrospira	2±16.45	11±34.98	3±14.32	-	11±26.22	-	3±18.20	3±11.43
Bumilleria	66±45.86	45±39.04	78±51.32	100±95.80	32±33.29	14±44.09	-	-
Bacillaria	22±45.09	8±28.23	3±17.00	22±45.09	26±44.21	-	-	-
Cladophora	11±41.00	6±28.03	-	-	-	-	-	-
Closterium	3±28.80	5±42.10	8±24.24	-	2±16.00	-	-	-
Cyclotella	22±34.09	32±44.21	11±22.01	44±24.11	2±25.98	6±30.91	12±15.15	21±20.91
Cocconeis	5±26.00	13±38.22	10±20.92	15±19.32	8±20.88	-	-	-
Cosmarium	8±16.29	4±28.65	3±12.54	-	-	-	-	-
Denticulla	22±56.22	12±25.29	30±33.92	88±67.23	52±54.20	27±22.10	21±40.21	-
Dinobryon	10±16.55	6±25.10	-	-	-	8±29.13	9±28.28	18±23.44
Eudorina	10±23.00	22±40.00	29±22.80	20±30.24	40±22.90	-	-	-
Euglena	11±33.90	20±22.97	9±20.10	10±32.16	9±33.29	8±18.00	13±22.23	16±19.04
Melosira	38±44.00	26±34.48	40±26.98	44±28.94	30±22.93	11±23.03	3±16.00	-
Microcystis	40±81.00	26±26.90	23±54.24	57±40.01	14±34.56	-	-	-
Navicula	43±66.09	22±24.24	21±70.00	25±28.99	34±24.82	12±19.26	6±22.01	3±18.45
Oscillatoria	-	8±25.23	11±29.16	5±28.28	-	-	-	-
Pandorina	28±38.26	18±28.10	25±29.34	11±22.54	-	-	-	-
Peridinium	-	-	-	-	-	11±25.18	8±34.94	10±26.19
Phacus	11±19.34	8±25.25	4±16.45	6±28.32	4±19.56	4±16.34	3±26.90	-
Scenadesmus	10±10.44	15±27.71	2±26.00	9±20.04	12±18.30	-	-	-
Synedra	20±38.09	10±21.45	14±26.43	27±28.92	11±21.88	2±20.18	8±20.33	9±16.84
Spyrogyra	88±42.09	56±50.20	87±50.33	64±12.92	21±10.32	-	-	-
Trachilomonas	11±22.10	-	6±16.60	9±20.00	11±30.90	8±12.12	2±10.15	-
Volvox	29±33.95	18±26.34	18±41.40	9±26.80	13±30.08	7±29.40	-	-
Zygnema	45±23.80	20±56.09	58±22.98	26±56.23	10±20.90	9±18.34	5±16.77	-
Un-identified	18	11	6	3	4	5	2	4
Zooplankton								
Asplanchna	9±20.45	10±16.89	6±11.40	11±16.05	6±19.10	-	-	-
Brachionus	10±20.11	7±16.25	8±12.45	14±13.00	12±24.24	-	-	-
Bosmina	10±22.93	5±19.45	6±18.00	-	-	3±11.10	5±12.22	2±13.38
Canthocamptus	10±11.38	8±28.09	10±22.03	12±20.40	3±12.04	-	-	-
Cyclops	10±33.09	11±22.20	8±35.03	4±18.80	10±29.22	-	-	-
Daphnia	3±20.90	5±14.22	4±11.20	8±10.19	7±20.00	3±14.25	2±8.16	-
Diaptomus	7±18.80	3±13.44	8±10.00	5±16.60	3±12.20	-	-	-
Filinia	-	15±20.40	20±25.00	10±18.18	11±20.20	3±16.80	4±10.22	2±14.38
Moina	3±22.00	7±16.62	5±18.24	-	-	-	-	-
Keratella	12±18.24	9±15.60	7±14.00	6±12.40	8±11.02	2±14.23	5±18.00	4±28.00
Polyarthra	15±20.29	11±16.26	18±20.00	6±16.80	5±10.10	-	-	-
Monnstyla	6±16.90	10±12.08	10±16.22	7±11.65	2±12.80	5±12.28	7±10.00	4±18.98
Un-identified	3	1	4	4	3	3	1	2

exhibited the mean highest manganese contamination level of 589.74±275.91 µg g^{-1} while the same was significantly lowest as 372.80±197.53 µg g^{-1} at Sukhrawa main drain (Table 1).

Planktonic Assay of the River and Tributaries: Table 2 shows the mean annual planktonic productivity (both phyto- and zooplankton) indices at five river site and three effluent discharging tributary sampling stations.

Myxophyceae, *Bacillariophyceae* and *Chlorophyceae* were the dominant groups distributed in the river stretch throughout the period of study. Among phytoplankton, *Aphanocapsa*, *Bumilleria*, *Bacillaria*, *Cladophora*, *Closterium*, *Cocconeis*, *Cosmarium*, *Eudorina*, *Microcystis*, *Oscillatoria*, *Pandorina*, *Scenadesmus*, *Spyrogyra*, *Volvox* and *Zygnema* indicated direct relationships with intensity of pollution as these genera were almost absent in highly polluted tributaries. However, the genera viz. *Aphanothece*, *Anabaena*, *Arthrospira*, *Cyclotella*, *Denticulla*, *Dinobryon*, *Euglen*a, *Navicula, Peridinium*, *Phacus* and *Synedra* showed considerable tolerance against heavy metals pollution. Among zooplankton, *Asplanchna*, *Brachionus*, *Canthocamptus*, *Cyclops*, *Diaptomus*, *Moina* and *Polyarthra* were almost absent at highly polluted sites. However, the genera viz. *Bosmina*, *Filinia*, *Keratella* and *Monnstyla* showed considerable tolerance against metallic ion pollution. *Daphnia* appeared to be a sensitive form against metallic pollution in water.

DISCUSSION

The present investigation revealed significant variations in metals toxicity of plankton in the river stretch and three main effluent discharging tributaries. The bulk discharges of industrial wastes and domestic sewage, by the three main tributaries, have adversely affected the quality of plankton in the river. Among the three tributaries, Degh nulla contributed significant metal's pollution in the plankton. This shows significant impact of metallic toxicity in water on its accumulation in plankton and adsorption by the sediments. Therefore, in an aquatic ecosystem plankton showed a great tendency to accumulate metals in their bodies from water and sediments (Khan *et al*., 1981; Javed and Hayat, 1999). The uptake and accumulation of heavy metals by the plankton from water and sediments are obvious and that may be the reason of alleviated levels of metals in plankton collected from highly polluted river sites. However, the accumulation of different metals in plankton followed the order Fe>Mn>Zn>Ni>Pb. The magnitude of heavy metals concentration of plankton and sediments in the rivers of Hong Kong followed the sequence: Zn>Pb>Cu>Cr>Ni>Cd (Zhou *et al*., 1998).

Among phytoplankton, *Aphanocapsa*, *Bumilleria*, *Bacillaria*, *Cladophora*, *Closterium*, *Cocconeis*, *Cosmarium*, *Eudorina*, *Microcystis*, *Oscillatoria*, *Pandorina*, *Scenadesmus*, *Spyrogyra*, *Volvox* and *Zygnema* indicated direct relationships with intensity of pollution as these genera were almost absent in highly polluted tributaries. However, the genera viz. *Aphanothece*, *Anabaena*, *Arthrospira*, *Cyclotella*, *Denticulla*, *Dinobryon*, *Euglena*, *Navicula*, *Peridinium*, *Phacus* and *Synedra* showed considerable tolerance against heavy metals pollution. Among the zooplankton, *Asplanchna*, *Brachionus*, *Canthocamptus*, *Cyclops*, *Diaptomus*, *Moina* and *Polyarthra* were almost absent at highly polluted sites. However, the genera viz. *Bosmina*, *Filinia*, *Keratella*, *Monnstyla* showed considerable tolerance against metallic ion pollution. *Daphnia* appeared to be a sensitive form against metallic pollution in water. *Spirulina*, *Nostoc*, *Oscillatoria* and *Anabaena* have been observed as dominant and resistant forms against heavy metals toxicity in the river while *Keratella*, *Tropica*, *Filinia* and *Polyarthra* were observed as tolerant forms against heavy metals toxicity (Unni, 1996). *Aphanizomenon*, *Bacillaria*, *Closterium*, *Cyclopedia*, *Cocconeis*, *Cosmarium*, *Chrococus*, *Denticula*, *Euglena*, *Spirulina*, *Spirogyra* and *Volvox* have been reported as the phytoplankton genera that showed considerable tolerance against heavy metals toxicity in the river (Javed and Hayat, 1996). Among the zooplankton, *Keratella* and *Filinia* appeared to be the genera tolerant against heavy metals toxicity while *Cyclops* and *Philodena* were the sensitive forms in the river Ravi. Many trace elements such as arsenic, cadmium, copper, lead and selenium can be toxic to aquatic biota (Eisler, 1985; Eisler, 1988) because plankton has the ability to concentrate heavy metals from their aquatic environment (Javed and Hayat, 1999).

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