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Uptake and Accumulation of Heavy Metals in Water and Planktonic Biomass of the River Ravi, Pakistan

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Abstract

The role of different taxa of plankton as biological sign of heavy metal pollution in the river Ravi from Lahore Siphon to Baloki Headworks has been studied. Levels of heavy metals investigated were higher than the permissible standards suggested for drinking water by EPA of USA and Pakistan. Aquatic biota exhibited higher tendency to amass metals in their bodies. The phytoplankton taxa showed direct relationship with the concentrations and amount of metals in river water as these taxa disappeared in extremely polluted sampling sites. The zooplankton taxa were almost absent due to heavy metal pollution. Among 13 zooplanktonic groups investigated, *Brachionus* and *Cyclops* were dominating with higher abundance. Present study indicated a strong affinity of plankton for the metal accumulation from the water.

Introduction

The rapid industrialization in Pakistan during recent years has adversely affected the river pollution due to influx of liquid industrial effluents and domestic wastes. Therefore, metallic pollution has increased over the years and has become more dangerous in the river downstream (Javed, 2006). River is not considered a source of water for drinking purposes but serves as an important habitat to numerous plant and animal species. Different kinds of effluents are being discharged from domestic and industrial activities into the river that accumulate into the basic food chain and move up

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through the higher trophic levels (Robin *et al*., 2012). The metals present in these effluents cause economic losses by affecting the migration of many aquatic animals.

The contamination of sea water, freshwater and estuarine water due to the direct exposure to atmospheric input, is probably the major source of pollution. This contamination is caused due the metals discharged by sewages and manufacturing industries such as food, beverages, palm oil refineries, petrochemical industry, manufacturing of fertilizers, textile, pulp paper, tanneries and sugar factories (Chua *et al*., 2000). The health status of rivers and its inhabitants is strongly dependent upon heavy metal profile in the river water and adversely increased by their ability to bio-concentrate in various plant, animal and human tissues and organs (Oroian *et al*., 2013; Ndome *et al*., 2014).

The plankton plays an essential role in the aquatic food chain of freshwater ecosystems compared to other important aquatic plants and animals, and it is characterized as vital food source obtained from the aquatic food chain. The phytoplankton and zooplankton serve as indicators of metal pollution due to their high predisposition to concentrate heavy metals (Roy *et al*., 2010). Water quality and chemistry is strongly affected by the discharge of nearby industries (Tampus *et al*., 2014) and sustainable management including effective political and legislative policies (Cojocariu *et al*., 2011; Ndome *et al*., 2014). Heavy metals are detected in higher concentrations in mixed zooplankton organisms near the coast due to the untreated discharge of many waste products of sewage treatment plants close to the coast or near the rivers (Rezai and Yusoff, 2011; Robin *et al*. 2012).

The river Ravi is a monsoon type of river. Survey of the study area revealed that the bulk discharges of untreated domestic and industrial effluents through different tributaries into the river Ravi at various points has adversely affected the water quality and aquatic life. It, therefore, requires effective monitoring of pollutants and heavy metals in the aquatic ecosystem because polluted water can cause paralysis, meningitis, cancer, sterility, schistosomiasis, poliomyelitis and filariasis in animals (Singh *et al*., 1982). Previous studies (Javed and Hayat, 1999; Javed, 1999; Javed, 2003; Javed, 2004) carried out by the other researchers have reported manganese, iron, lead nickel and zinc toxicity in the river Ravi water and the biota. No comprehensive study is documented as far as harmful consequences of metal on the phyto- & zooplankton abundance are considered. Present study is novel in nature as previous studies have focused only on fewer genera and could not be used to assess the magnitude of problem and the health status of ecosystem of river. The river Ravi sites and its tributaries (14 sampling stations) investigated during the present research endeavor were analyze for the environmental impact of metals on the planktonic abundance. The aim of the study was also to improve awareness on the lack of studies concerned with evaluation of heavy metals especially in the plankton (zooplankton and phytoplankton genera) in this area.

Materials and Methods

Study Area

The river Ravi enters Pakistan near the village tadyal, Shakargarh after its origin from India. The study was conducted in areas of Lahore Siphon to Baloki Headworks (72 Km) located on river Ravi. Degh Fall and Hudiara nulla are the main tributaries that put pollutants into the river. The untreated domestic waste, industrial liquid and solid wastewater discharged through these main tributaries along the bank converted river water into dark grey liquid with foul smell.

Sampling Stations

Fourteen sampling sites were selected for the collection of water and plankton. Seven river Ravi sites viz: Lahore Siphon (R1), Shahdera Bridge (R2), Purani Bheni (R3),

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Mohnalwal (R4), Chaki Ghera (R5), Sunder (R6) and Baloki Headworks (R7) were nominated. The effluent discharging tributaries viz: Shadbagh nulla (T1), Farrukhabad nulla (T2), Munshi Hospital nulla (T3), Taj Company nulla (T4), Hudiara nulla (T5), Degh Fall nulla (T6) and Qadarabad Baloki link canal (T7) were selected. Samples of the water and plankton from 14 sampling sites were collected on fortnightly basis (n=24) for one year period from February, 2006 to January, 2007.

Samples of water from river sites and its tributaries were collected at a depth of 0.5 m and filtered by using membrane filters of 0.45 µm. Water samples were analyzed through Atomic Absorption Spectrophotometer (Perkin Elmer, AAnalyst-400) by following the methods of APHA, 1998 (3500-Cd B, 3500-Cr B, 3500-Co B and 3500-Cu B).

The plankton samples were also collected by filtering nearly 90-100 liter of water by using the plankton net of 10 µm pore capacity. The samples of phytoplankton and zooplankton were identified with the help of plankton splitter and camera fitted microscope according to the manuals of Johnson & Allen, 2005; Vuuren *et al*., 2006. Samples were digested using HNO_3 and $HClO_4$ (1:3 v/v) and analyzed for Cd, Cr, Co and Cu metals by using methods of APHA (1998), respectively. The planktonic abundance on the dry weight basis was determined by the evaporation method (Javed, 1988) through the following formula:

Dry weight of Plankton Biomass (Abundance) = Total solids (TS) – Total dissolved solids (TDS)

TS and TDS were calculated by the evaporation method. The river water sample of 1 L taken in pre-weighed beaker was placed in oven at 103°C for evaporation. The beakers were weighed again to determine TS and TDS. Sensitivity or resistance of the phytoplankton & zooplankton was determined on the basis of abundance of phytoplankton and zooplankton (individual per liter of water). Sensitive genera could not tolerate metal toxicity and showed less planktonic abundance whereas plankton with the high abundance indices was considered resistant. Descriptive statistics, i.e., means and standard deviations were calculated for all the samples. Analysis of Variance and comparison of means were performed to find statistical differences among various variables. STATISTICA and MICROSTAT software packages of computer were used for the analyses of data.

Results

Comparative analysis of metals contents in water of River Ravi sites and its tributaries revealed that concentration of chromium and copper were higher in its tributaries as compared to river sites (Figure 1 & 2).

Cadmium concentration in the water samples collected from the different sites (River and tributaries) varied significantly. Among the river sites, the highest concentration appeared in R_6 and the lowest appeared in R_1. The concentration in water samples ranked from highest to lowest was as follows: R_4, R_5, R_6, R_3, R_2, R_7 and R_1 in the river sites as shown in Figure 1. Among the tributaries, T_1 had the highest Co concentration while it was lowest at T_7. The other tributaries showed statistically non-significant difference for Co concentrations.

Cd in the plankton samples collected from R_4, R_5 and R_6 showed higher contamination. Accumulation of Cr in the plankton samples collected from the river sites and its tributaries varied significantly. Among effluent discharging tributaries, T_2 showed significantly higher Cr concentration while T_7 show lowest Cr concentration in plankton samples. Highly significant differences among sampling sites for Co accumulation in plankton were observed during present investigation. Concerning the river sampling sites, the plankton collected from R_6 had the highest mean contamination while it was lowest in the plankton samples at R_1. Levels of Co in the plankton samples collected from all

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the tributary sites showed significant fluctuations. The plankton samples of the T_2 site showed highest mean annual concentration while it was lowest at T_7 (Figure 2).

Cu concentration in the plankton collected from the river sites showed maximum Cu concentration at R_6 and minimum at R_1. However, there was non-significant difference in Cu concentrations among the river sites of R_4, R_3 and R_2. The lowest Cu concentration was recorded at tributary, T_7 while highest was recorded at T_4 sampling site.

Planktonic Abundance

The mean annual abundance of phytoplankton and zooplankton of both the river and tributary sites are represented in Table 1 & 2. *Myxophyceae*, *Bascillariophyceae* and *Chlorophyceae* were the dominating groups distributed in the river. Among phytoplankton, *Carteria*, *Chlorella*, *Geminella*, *Rhizoclonium* and *Synedra* were sensitive genera against heavy metal pollution with low phytoplankton abundance (individual per litre of water). While *Actinastrum*, *Amphora*, *Chroococcus*, *Cymbella*, *Pediastrum*, *Spirulina* and *Staurastrum* showed considerable tolerance against heavy metal pollution reflected by the higher abundance of phytoplankton and zooplankton. *Asterionella*, *Caloneis*, *Diatoma*, *Euastrum*, *Frustulia*, *Oedogonium*, *Pinnularia*, *Stauroneis* and *Ulothrix* were almost absent or detected in significantly low density indicating the direct relationships of phytoplankton and zooplankton abundance with the intensity of metal's pollution (Table 1).

Among zooplankton, on the river sites, *Brachionus*, *Filinia*, *Keratella* and *Leptodora* appeared tolerant against the heavy metal pollution. However, *Cyclops, Difflugia*, *Chironomus* and *Anopheles* (insect larvae) showed considerable sensitivity against Cd, Cr, Co and Cu toxicity (Table 2). Zooplankton genera (*Bosmina*, *Daphnia*, *Diaptomus, Trachyleberis*, *Vorticella*, *Nehalennia*, *Amphizoa* and *Mysis*) appeared most sensitive, being almost absent at highly contaminated sites, which indicates adverse effect of metals.

The phytoplankton taxa viz. *Chlorella*, *Closterium*, *Pinnularia*, *Synedra* and *Zygnema* showed least tolerance against heavy metal as they were absent in highly polluted tributaries. However, *Bumilleria*, *Cocconeis*, *Frustulia*, *Geminella*, *Melosira* and *Scenedesmus* were sensitive forms showing sensitivity against metal pollution. While *Aphanothece*, *Aphanocapsa*, *Bacillaria*, *Cyclotella*, *Chroococcus*, *Navicula* and *Tabellaria* showed tolerance against heavy metal.

Zooplanktonic indices showed variability among tributary sites. *Canthocamptus* (a benthic herpacticoid), *Daphnia*, *Monostyla* and *Philodina* were almost absent at highly polluted sites. *Daphnia*, *Monostyla* and *Philodina* were highly sensitive zooplankton. *Brachionus*, *Bosmina*, *Diaptomus*, *Filinia*, *Keratella* and *Polyarthra* showed considerable tolerance against heavy metal pollution, demonstrating higher values of planktonic abundance.

Discussion

Present study evaluated Cd, Cr, Co and Cu levels and abundance for all genera of phyto- and zooplankton as bio-indicator of metallic pollution for 14 sampling sites of river Ravi, which has been documented here for the first time, as several previous studies (Javed, 2006; Rauf and Javed, 2007; Jabeen and Javed, 2011) conducted on river Ravi lack any data on abundance in terms of biomass production in these major phyto- and zooplankton genera. Metal uptake and planktonic abundance in phyto- and zooplankton genera collected from 14 sampling sites including both river sites and tributaries has been conducted as a holistic investigation (based on all the sites and tributaries) for the first time, as in previous studies (Javed, 1999; Javed

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and Hayat, 1999; Mahmood *et al*., 2000; Ubaidullah *et al*., 2004; Javed, 2006) only small number of planktonic genera from fewer sites have been documented, whereas present study confirms the overall status of metal toxicity in all genera of plankton inhabiting river Ravi.

Jabeen and Javed (2011); Jabeen *et al*. (2011) also studied different metals (arsenic, chromium, barium, nickel and zinc) in water at three river sites. In the tributaries both T_2 and T_3 showed the highest mean Cd concentration. However, the difference for Cd concentration between T_2, T_3 and T_4 were statistically non-significant. This indicates that this particular area is very polluted, which is in line with the studies of Safahieh *et al*. (2011). Altidang and Yigit (2005) reported higher concentration of Cd (0.11 mgL^{-1}) and Pb (0.86 mgL^{-1}) in lake Beysehir in Turkey while higher Cu (0.14), Pb (0.03) and Cd (0.04 mgL^{-1}) were reported by Elmaci *et al*. (2007) in lake Uluabot in Turkey.

Present study reveals heavy metals accumulation in these water bodies that caused decrease in abundance of plankton, which is very important for ecosystem functioning since plankton could become food for other organisms and might also lead to metal bioaccumulation in food chains (Akhtar *et al*., 2005; Javed, 2006). The highest accumulation of Cd in aquatic food chain would be hazardous to secondary consumer (Ruangosomboon and Wongrat, 2006).

Levels of Co in the plankton samples collected from all tributary sites were significantly varied. T_2 sample site showed highest mean annual concentration while it was lowest at T_7. Javed and Mahmood (2000) and Javed (2003) analyzed different metals (zinc, iron, manganese and lead) in plankton in contrast to present studies. They revealed that metal uptake and accumulation was dependent on physico-chemical variables of the water and sediments (Jabeen *et al*., 2018).

Present study revealed significant variations in mean levels of Cd, Cr, Co and Cu and heavy metal both in river and tributary water followed the order as Cu>Cr>Cd>Co. Bahnasawy *et al*. (2011) reported plankton abundance and observed increasing metal trend as zinc> copper>lead>cadmium. This trend may be attributed to huge plankton surface area as compared to their mass (Ravera, 2001). Results are similar to Elmaci *et al*. (2007) who also demonstrated higher levels of metals in plankton whereas Tulonen *et al*. (2006) described higher Cu concentration and lower levels of Zn, Pd and Cd. Javed and Mahmood (2000); Javed (2003) and Jabeen *et al*. (2018) analyzed different metals (zinc, iron, manganese and lead) in the plankton in contrast to present studies. They revealed that metal uptake and accumulation was dependent on physico-chemical variables of the water and sediments.

The zooplankton abundance of 18 major genera in response to metals (Cu, Co, Cd and Cr) toxicity present in river Ravi water has been reported for the first time as study area still lacked any information on abundance of these genera, since Javed and Mahmood (2000) investigated metals (Pb, Ni, Fe & Mn) and Javed (2005) studied metal toxicity in sediments and fish.

During present investigation, *Brachionus*, *Bosmina*, *Diaptomus*, *Filinia*, *Keratella* and *Polyarthra* showed considerable tolerance against the heavy metal pollution by demonstrating higher values of abundance of phytoplankton and zooplankton. The findings are in accordance with Javed (2006) who reported *Scenedesmus*, *Eudorina*, *Aphanocapsa*, *Bacillaria*, *Cladophora*, *Oscillatoria* and *Pandorina* were the genera, which showed least tolerance against metal toxicity in the sampling area ranged from Baloki headworks to the Sidhnai barrage. Higher metal levels in tributaries observed in present study might be attributed to high influx of heavy metals through the liquid industrial effluents and domestic waste discharged in the tributaries. Results are in accordance with Hassan (2016) and Strzebonska *et al*. (2017).

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Conclusion

In conclusion, higher concentrations of metals found in the water and plankton samples collected from the river Ravi and its tributaries receiving wastewater discharges of industries and urban areas have adversely affected the phyto- and zooplankton genera residing in metal polluted ecosystem. Strict mitigation measures must be implemented to minimize concentration of heavy metals in water and plankton as heavily loaded communal wastewater would become food for other organisms and ultimately metallic toxicity will reach to other highest trophic level, such as fish. Due to the toxic effect of heavy metals on abundance of planktonic population, phyto- and zooplankton can be utilized as bio-indicator of metallic pollution.

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Table 1. Planktonic abundance indices (individual per litre of water) of the river sites.

PLANKTON GENERA							
	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**
A. PHYTOPLANKTON							
Actinastruun	11.00±1.59	28.00±2.65	26.00±2.27	37.00±3.02	24.00±2.19	51.00±3.89	10.00±1.51
Amphora	40.00±3.45	18.00±2.09	13.00±1.89	13.00±1.89	26.00±2.27	13.00±1.89	18.00±2.09
Anabaena	70.00±4.85	18.00±2.09	28.00±2.65	26.00±2.27	20.00±2.51	-	59.00±4.01
Aphanizomenon	80.00±5.01	14.00±1.95	29.00±2.75	19.00±2.41	66.00±4.18	12.00±1.85	37.00±3.02
Asterionella	14.00±1.95	-	-	-	-	-	26.00±2.27
Caloneis	10.00±1.51	-	-	-	-	-	13.00±1.89
Carteria	14.00±1.95	-	3.00±0.85	-	7.00±1.11	-	8.00±1.41
Chlamydomonas	11.00±1.62	-	-	-	-	-	-
Chlorella	26.00±2.27	3.00±0.85	-	-	-	-	12.00±1.85
Chlorococcum	16.00±2.05	-	-	-	-	-	3.00±0.85
Chroococcus	-	5.00±1.01	2.00±0.51	5.00±1.01	4.00±0.98	7.00±1.11	-
Coelastrum	-	-	-	-	4.00±0.98	-	-
Coelospharium	14.00±1.95	3.00±0.85	-	-	-	4.00±0.98	16.00±2.05
Cymbella	23.00±2.10	1.00±0.51	11.00±1.62	-	16.00±2.05	6.00±1.20	21.00±2.58
Diatoma	13.00±1.89	-	-	-	-	-	-
Euastrum	15.00±2.01	-	-	-	-	-	3.00±0.85
Euglena	96.00±7.14	-	18.00±2.09	20.00±2.50	20.00±2.50	12.00±1.85	4.00±0.98
Frustulia	-	-	-	-	-	-	-
Geminella	9.00±1.42	7.00±1.11	-	7.00±1.11	2.00±0.51	-	12.00±1.85
Oedogonium	8.00±1.41	-	-	-	-	-	3.00±0.85
Pediastrum	19.00±2.41	-	12.00±1.85	6.00±1.20	3.00±0.85	3.00±0.85	2.00±0.51
Pinnularia	28.00±2.65	-	-	-	-	-	-
Rhizoclonium	40.00±3.45	-	18.00±2.09	-	28.00±2.65	11.00±1.62	-
Spirulina	28.00±2.65	3.00±0.85	78.00±4.91	21.00±2.58	97.00±6.24	17.00±2.07	10.00±1.51
Staurastrum	-	14.00±1.95	13.00±1.89	15.00±2.01	26.00±2.27	11.00±1.62	9.00±1.42
Stauroneis	11.00±1.62	-	-	-	-	-	-
Synedra	14.00±1.95	11.00±1.62	11.00±1.62	-	-	-	-
Tabellaria	-	29.00±2.75	78.00±4.91	15.00±2.01	93.00±6.01	-	6.00±1.20
Ulothrix	17.00±2.07	-	-	-	-	-	-
Un-identified	8.00	17.00	8.00	2.00	12.00	14.00	8.00
B. ZOOPLANKTON							
Brachionus	19.00±2.41	11.00±1.62	18.00±2.09	21.00±2.58	19.00±2.41	11.00±1.62	12.00±1.85

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Bosmina	14.00±1.95	-	-	-	-	-	-
Cyclops	-	17.00±2.07	19.00±2.41	-	17.00±2.07	11.00±1.62	-
Cypris	4.00±0.98	-	-	-	-	-	5.00±1.01
Daphnia	5.00±1.01	2.00±0.51	-	-	-	-	-
Diaptomus	7.00±1.11	-	-	-	-	-	3.00±0.85
Difflugia	-	-	3.00±0.85	2.00±0.51	2.00±0.51	-	-
Filinia	9.00±1.42	7.00±1.11	8.00±1.41	10.00±1.51	5.00±1.01	4.00±0.98	-
Keratella	7.00±1.11	9.00±1.42	11.00±1.62	10.00±1.51	8.00±1.41	7.00±1.11	10.00±1.51
Leptodora	-	3.00±0.85	2.00±0.51	3.00±0.85	2.00±0.51	5.00±1.01	-
Trachyleberis	-	3.00±0.85	-	-	-	3.00±0.85	-
Vorticella	-	-	-	-	-	-	4.00±0.98
Chironomus	3.00±0.85	2.00±0.51	-	-	-	-	3.00±0.85
Anopheles	5.00±1.01	11.00±1.62	-	-	-	3.00±0.85	5.00±1.01
Notonecta	2.00±0.51	3.00±0.85	-	-	-	-	-
Nehalennia	-	6.00±1.20	-	-	-	-	2.00±0.51
Amphizoa	-	3.00±0.85	-	-	-	-	3.00±0.85
Mysis	3.00±0.85	-	-	-	-	-	2.00±0.51
Un-identified	12.00	20.00	12.00	9.00	4.00	7.00	12.00

Table 2. Planktonic abundance indices (individual per litre of water) of tributaries.

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Table 2. Planktonic abundance indices (individual per litre of water) of tributaries.

PLANKTON GENERA							
PHYTOPLANKTON							
	T1	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
Aphanothece	5.00±1.01	8.00±1.40	4.00±0.98	3.00±0.85	3.00±.0.85	4.00±0.98	6.00±1.20
Anabaena	9.00±1.42	9.00±1.42	10.00±1.51	10.00±1.51	5.00±1.01	11.00±1.62	9.00±1.41
Aphanocapsa	10.00±1.50	7.00±1.11	9.00±1.42	10.00±1.50	7.00±1.11	8.00±1.40	7.00±1.11
Aphanizomenon	10.00±1.51	9.00±1.42	23.00±2.81	26.00±3.01	14.00±1.95	26.00±3.01	20.00±2.51
Arthrospira	-	8.00±1.40	-	-	-	5.00±1.01	5.00±1.01
Bumilleria	1.00±0.51	-	3.00±0.85	5.00±1.01	10.00±1.51	19.00±2.41	16.00±2.05
Bacillaria	-	15.00±2.01	10.00±1.50	8.00±1.41	20.00±2.51	19.00±2.41	13.00±1.89
Chlorella	-	-	-	-	-	15.00±2.01	12.00±1.85
Cladophora	12.00±1.85	5.00±1.01	4.00±0.98	2.00±0.51	9.00±1.41	4.00±0.98	5.00±1.01
Closterium	-	-	-	-	-	12.00±1.85	10.00±1.51
.Cocconeis	-	-	-	19.00±2.41	9.00±1.41	14.00±1.95	11.00±1.62
Cyclotella	5.00±1.01	9.00±1.42	10.00±1.51	13.00±1.89	8.00±1.40	7.00±1.11	9.00±1.42
Cymbella	-	5.00±1.01	-	-	19.00±2.41	17.00±2.07	15.00±2.01
Chroococcus	25.00±3.02	56.00±3.99	17.00±2.07	15.00±2.01	-	-	-
Euglena	13.00±1.89	85.00±6.42	21.00±2.58	25.00±2.61	10.00±1.51	12.00±1.85	20.00±2.50
Fragilaria	-	2.00±0.71	11.00±1.59	-	-	21.00±2.58	25.00±2.61
Frustulia	10.00±1.51	5.00±1.01	-	-	25.00±2.61	-	-
Geminella	5.00±1.01	1.00±0.45	-	5.00±1.01	32.00±2.98	-	-
Melosira	-	18.00±2.09	-	-	16.00±2.03	-	-
Navicula	11.00±1.59	9.00±1.41	11.00±1.59	8.00±1.40	16.00±2.03	-	17.00±2.07
Oscillatoria	17.00±2.07	18.00±2.09	-	-	-	14.00±1.95	19.00±2.41
Pinnularia	-	-	-	-	-	8.00±1.40	10.00±1.51
Rhizoclonium	-	15.00±2.01	18.00±2.09	-	-	-	-
Scenedesmus	-	11.00±1.59	8.00±1.41	-	-	18.00±2.09	15.00±2.01
Spirulina	11.00±1.59	18.00±2.09	21.00±2.58	15.00±2.01	18.00±2.09	7.00±1.11	10.00±1.51
Synedra	8.00±1.41	-	-	-	-	-	-
Tabellaria	11.00±1.59	8.00±1.41	6.00±1.20	15.00±2.01	13.00±1.89	17.00±2.07	16.00±2.03
Zygnema	-	-	25.00±2.61	-	-	-	-
Un-identified	12.00	17.00	3.00	8.00	12.00	14.00	8.00
ZOOPLANKTON							
Asplanchna	3.00±0.85	-	-	2.00±0.71	2.00±0.71	3.00±0.85	2.00±0.71

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Brachionus	15.00±2.01	16±2.03	10.00±1.51	8.00±1.40	4.00±0.98	4.00±0.98	8.00±1.40
Bosmina	8.00±1.40	7.00±1.11	7.00±1.11	9.00±1.42	8.00±1.40	5.00±1.01	4.00±0.98
Canthocamptus	-	-	-	-	-	-	-
Cyclops	2.00±0.71	18.00±2.09	-	-	11.00±1.59	21.00±2.58	29.00±2.74
Daphnia	-	-	-	-	-	2.00±0.71	3.00±0.85
Diaptomus	1.00±0.45	-	-	-	7.00±1.11	-	5.00±1.01
Filinia	6.00±1.02	7.00±1.11	12.00±1.85	9.00±1.42	7.00±1.11	8.00±1.40	10.00±1.51
Keratella	-	7.00±1.11	13.00±1.89	11.00±1.59	12±1.85	15.00±2.01	15.00±2.01
Monostyla	-	-	-	-	-	13.00±1.89	7.00±1.11
Philodina	-	-	-	-	-	4.00±0.98	5.00±1.01
Polyarthra	12.00±1.85	7.00±1.11	8.00±1.40	6.00±1.02	12.00±1.85	7.00±1.11	5.00±1.01
Un-identified	5.00	4.00	10.00	5.00	1.00	4.00	2.00

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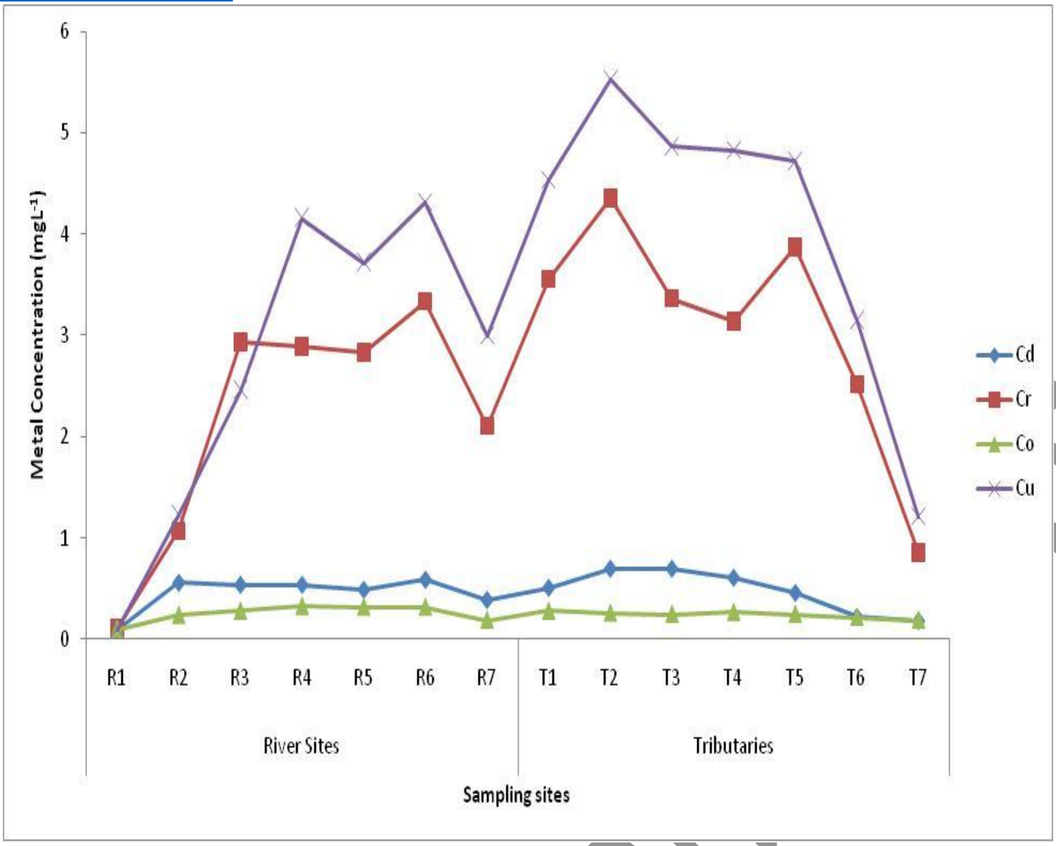

Figure 1. Comparison of heavy metal contents in water of River Ravi and its tributaries.

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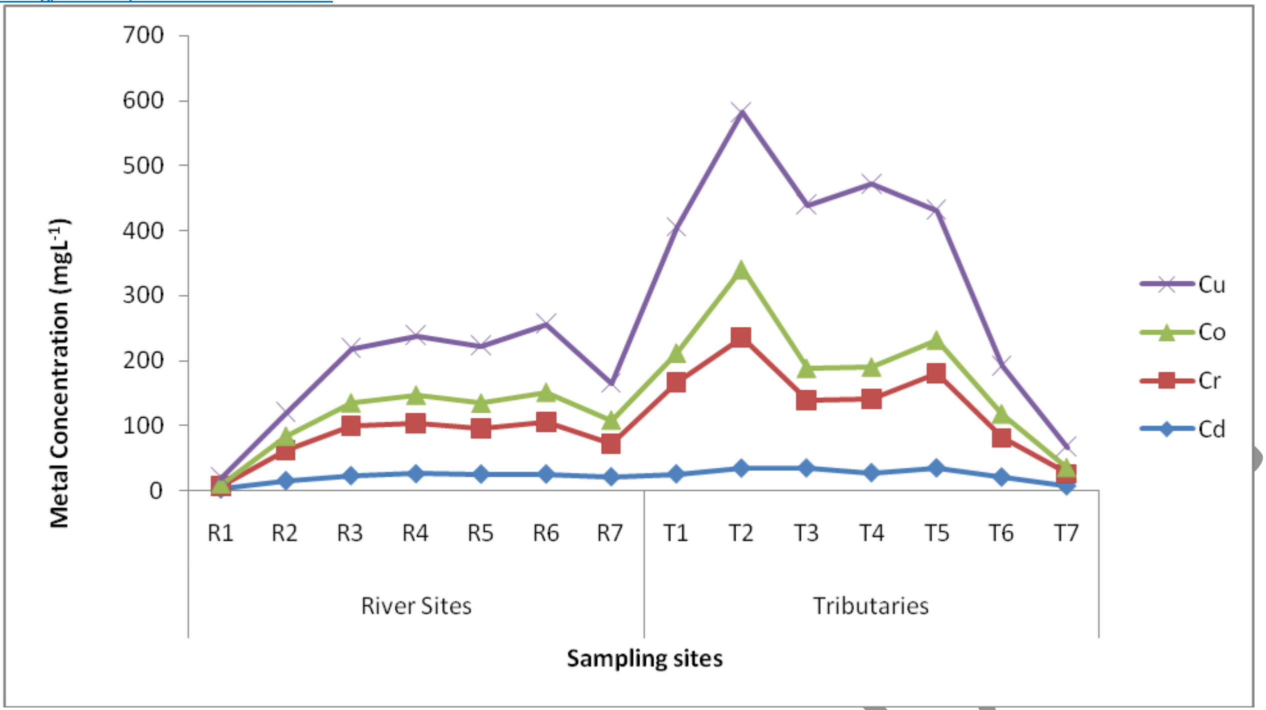

Figure 2. Comparison of heavy metal contents in plankton of River Ravi and its tributaries.