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Impact of Waste Disposal on the Uptake and Accumulation of Heavy Metals in the Planktonic Biomass of the River Ravi

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ABSTRACT

This study deals with the determination of metals contamination levels of planktonic biomass in the river Ravi stretch from Baloki headworks to Sidhnai barrage. These studies revealed significant variations in metals toxicities of plankton in the river and the three main effluent discharging tributaries. The bulk discharges of polluted water into the river have adversely contaminated the plankton. Plankton showed significantly direct relationship, for the accumulation of manganese, with water temperature in the river while inversely significant for lead and nickel toxicities in tributary water. The metals toxicity of plankton in both river and tributaries (except for nickel in river and both iron and manganese in tributaries) showed inverse relationships with total hardness of water.

Key Words: Heavy metals; Planktonic biomass; River Ravi; Tributaries; Toxicity

INTRODUCTION

One of the most significant man-made changes in the aquatic habitat has been the addition of chemicals, containing a lot of heavy metals into them. Such inputs to water can be derived from a variety of sources, some of them are obvious and others less so. In aquatic ecosystems, heavy metals have received considerable attention due to their toxicity and accumulation in biota (Mason, 1991). Aquatic organisms have been used in comparative monitoring of pollution effects in different systems and to locate sources of toxicants (Phillip, 1989). Bio-monitoring approach has proved to be promising as a reliable means of quantifying biological effects of complex effluents (Birge *et al*., 1985). Although a large number of aquatic organisms have been used for assessment, some workers have recognized the importance of algae as indicator in assessment and evaluation of pollution (Prasad & Manjula, 1980; Nandan & Patel, 1986; Javed & Hayat, 1996). Significant correlations between the concentrations of metals in planktonic biomass and water revealed the capability of plankton to concentrate heavy metals from their aquatic environment (Harding & Whitton, 1981; Javed & Hayat, 1996). Heavy metals in water and sediments have an impact on aquatic vegetation to accumulate metals in their bodies also (Khan *et al*., 1981). Ajmal and Razi-ud-Din (1988) reported high concentrations of cobalt, chromium, copper, iron, manganese, nickel, lead and zinc in submerged vegetation of Hindon river (India) on dry weight basis. Bioaccumulation of different metals in plankton varied significantly (Bradley & Sprague, 1985). Metals are the problem of magnitude and of ecological significance due to their high toxicity and ability to accumulate in living organisms. This study was, therefore, carried-out to investigate the heavy metals toxicity of plankton in the river Ravi stretch from Baloki headworks to Sidhnai barrage.

MATERIALS AND METHODS

Five river (from Baloki headworks to Sidhnai barrage) site sampling stations viz. Baloki headworks (R1), Syedwala (R2), Maripattan bridge (R3), Kamalia-Chichawatni “K.C. bridge”(R4), Sidhnai barrage (R5) and three effluent discharging tributaries viz. Degh nulla (T1), Sammundri main drain (T2) and Sukhrawa main drain (T3) were selected for the study of metals toxicity in the plankton. Plankton samples were collected on fortnightly basis and dry weights were determined through evaporation method. The physico-chemical parameters viz. water temperature, dissolved oxygen, pH, electrical conductivity, total hardness and magnesium were also studied, on fortnightly basis, by following the methods described by A.P.H.A. (1971). Dry samples of planktonic biomass were digested in Perchloric and Nitric acids and volumes were made for the detection of heavy metals viz. iron, zinc, lead, nickel and manganese through the methods of S.M.E.W.W. (1989). Data were statistically analyzed through two-way classification (Factorial Experiment) by following Steel and Torrie (1986). Analysis of variance and Duncan's Multiple Range Test (Duncan, 1955) were performed to find-out statistically significant differences among various parameters under study. Regression analyses were performed to find-out relationships / trends among various parameters under study. MSTATC and MICROSTAT packages of the computer were used to analyze the data.

RESULTS

Table I shows the mean concentrations of iron, zinc, lead, nickel and manganese in the plankton samples collected from the five river site sampling stations and three main effluent discharging tributaries.

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

Zinc. Analysis of variance shows highly significant differences among river site sampling stations and effluent discharging tributaries for zinc contamination in plankton samples. In the river course, the plankton at Syedwala had the mean highest zinc concentration of 290.13 ± 117.70 µg g^{-1} while the same was minimum at Baloki headworks (235.17 ± 99.35 µg 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 content than Sukhrawa main drain and Degh nulla. However, the differences among all the

Table I. Metals toxicity of plankton in the river and tributaries waters

Sampling Station	Mean Metal Concentrations (µgg^{-1})				
	Iron	**Zinc**	**Lead**	**Nickel**	**Manganese**
Balokiheadworks (R1)	12818.03±8996.07b	235.17±99.35e	35.98±19.27c	57.16±38.86e	516.08±244.67d
Syedwala (R2)	5154.06±2972.86g	290.13±117.70cd	43.61±20.65a	54.88±34.16f	512.09±275.59d
Maripattanbridge (R3)	6309.96±2540.54f	275.93±159.89d	34.57±18.01d	63.69±43.99b	527.91±371.80bc
K.C.bridge (R4)	7229.46±2230.96e	287.76±130.81cd	32.05±13.35f	61.42±21.28c	525.99±264.37c
Sidhnaibarrage (R5)	9122.42±3718.60d	265.20±106.03de	30.15±9.16g	60.26±28.99d	530.95±271.02bc
Deghnulla (Drain)(T1)	10441.37±5239.08c	317.15±172.37c	41.54±39.08b	76.03±62.30a	589.74±275.91a
Sammundrimaindrain (T2)	16849.91±4554.92a	610.49±229.31a	24.09±15.22h	39.47±24.62g	534.62±158.51b
Sukhrawamaindrain (T3)	4575.77±1776.22h	393.50±135.62b	33.30±27.72e	63.76±26.74b	372.80±197.53e
SE	31.3345	11.8685	0.3189	0.4968	2.4525

Means with similar letters in a single column are statistically similar at $p < 0.05$.

Table II. Regression of metals toxicity (µg g^{-1}) of plankton (y) on the physico-chemical variables

Dependent variable (y)	Regression Equation	r/MR	R^2
RIVER			
Iron	y = 10638.34 - 380.9956 (D. O.)	- 0.5602	0.3138
	NS		
	SE = 216.1026		
Zinc	y = No variables meet criteria.		
Lead	y = No variables meet criteria.		
Nickel	y = - 192.98 + 33.4008 (pH)	0.6831	0.4666
	p< 0.05		
	SE = 16.5112		
Manganese	y = 708.83 - 0.4565 (E. C.) - 31.6980 (D. O.) + 11.3580 (Temp.)	0.5453	0.2974
	p < 0.01 p < 0.01 p < 0.01		
	SE = 0.1128 9.7845 4.0719		
TRIBUTARIES			
Iron	y = 6052.95 - 1449.7284 (D. O.) + 218.8174 (Temp.)	0.3722	0.1385
	p < 0.01 NS		
	SE = 538.3904 109.7577		
Zinc	y = 392.38 - 0.3641 (T. H.) + 0.0860 (E. C.) - 39.0974 (D. O.)	0.5710	0.3260
	p < 0.01 p < 0.01 p < 0.05		
	SE = 0.0826 0.0253 18.2619		
Lead	y = 73.24 + 1.4790 (Temp.)	0.7313	0.5348
	p < 0.01		
	SE = 0.5035		
Nickel	y = 366.66 - 0.0056 (E. C.) - 31.3000 (pH) + 1.6055 (Temp.)	0.7982	0.6371
	NS p < 0.05 p < 0.05		
	SE = 0.0032 13.2689 0.7773		
Manganese	y = 357.20 + 0.2237 (T. H.)	0.6012	0.3614
	p < 0.01		
	SE = 0.0462		

r = Correlation coefficient; R^2 = Coefficient of determination; SE = Standard error; DO = Dissolved oxygen (mg L^{-1});
EC = Electrical conductivity(µS); Temp. = Water temperature (^oC); TH = Total hardness (mg L^{-1}); NS = Non-significant

three tributaries, for zinc contamination levels, were statistically significant (Table I).

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

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

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 µg g^{-1}) while the lowest concentration was observed at Syedwala (512.09 ± 275.59 µg 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, Degh nulla 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 I).

Toxicity of Plankton Dependent Upon Physico-chemistry of Water

River. Dissolved oxygen of water appeared as a single variable which showed inverse relationship with the accumulation of iron by the plankton. However, the regression coefficient for this equation was non-significant (Table II). As far as zinc and lead accumulations in plankton were concerned, no variable meet the criteria of step-wise regression method. Nickel toxicity was positively ($p < 0.05$) dependent upon pH of water. The accumulation of manganese in plankton showed negatively significant dependence on electrical conductivity and dissolved oxygen while the same for temperature was positive and highly significant (Table II).

Tributaries. The plankton collected from three main effluent discharging tributaries showed negatively significant dependence on dissolved oxygen while the same was positive but non-significant on temperature of water. This relationship explains 13.85 percent variations in iron toxicity of plankton. Three variables viz. total hardness, electrical conductivity and dissolved oxygen exerted 32.60% variations towards zinc toxicity in plankton. The partial regression coefficients for total hardness and dissolved oxygen were negative while of electrical conductivity appeared positive and highly significant. Water temperature was the only variable that showed positive but highly significant regression on lead toxicity in plankton. The accumulation of nickel in plankton was negatively dependent upon electrical conductivity and pH while temperature had significantly positive regression. The partial regression coefficients for all the variables were significant at $p<0.05$ except electrical conductivity. Manganese toxicity showed positive and highly significant dependence on total hardness of water. This regression model explains only 36.14% variations of manganese toxicity in plankton (Table II).

DISCUSSION

These studies revealed significant variations in metal toxicities of plankton in the river 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. The occurrence of heavy metals in the aquatic habitats is dependent upon a wide-range of chemical, biological and environmental factors. Among the physico-chemical factors, an important factor which influences the availability of different heavy metals in an aquatic ecosystem is the H^+ concentration (Polprasert, 1982). The accumulation of all the metals, except manganese in the plankton of river Ravi, showed direct relationships with the pH of water. However, in tributaries, lead, nickel and manganese accumulations were negatively dependent upon pH of water. Plankton showed significantly direct relationship, for the accumulation of manganese, with water temperature in the river while inversely significant for lead and nickel toxicities in the tributary water. There is no single pattern for effects of temperature on toxicity of pollutants in aquatic organisms. Temperature change in a given direction may increase or decrease toxicity, depending upon the toxicities and species (Macleod & Pessah, 1993). The results obtained did not yield directly the biological toxic potentiality of a given water body (Kramer & Botterweg, 1991), which could not be disclosed in a single evaluation. However, both iron and zinc contaminations in plankton showed positively non-significant dependence on temperature of water. An important modifying factor in an aquatic habitat is temperature that affected ionization also. Lloyd (1992) showed a 2.50 fold increase in metals toxicity for an increase in temperature from 7 to 20 ºC. Jackson (1988) reported increase in metals uptake by benthos with the decrease in water temperature. However, bio-dilution had non- significant effect on mercury accumulation by benthos or plankton. The potential of plankton to concentrate heavy metals from aquatic environments into their bodies is evident (Harding & Whitton, 1981). The metals toxicity of plankton in both river and tributaries (except for nickel in river and both iron and manganese in tributaries) showed inverse relationships with total hardness of water also. Water-borne metals generally exhibit their greatest toxicity to aquatic organisms in soft water of low pH and low dissolved organic carbon (Novelli *et al.*, 1998). This is because the hardness cations (Mg^{2+} and Ca^{2+}) compete with heavy metal cations for binding sites within the organism.

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