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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (12): 2165-2168, 2000

Studies on the Metal Toxicity of Plankton in the River Ravi

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Abstract: Metals toxicity of plankton in the river Ravi stretch, from Shahdera to Baloki headworks, has been studied. Among phytoplankton, *Aphanocapsa, Bacillaria, Closterium, Cyclotella, Cocconeis, Cosmarium, Denticulla, Dinobryon, Euglena, Gloeocapsa, Pinnularia, Spirulina* and *Spirogyra* showed considerable tolerance against heavy metals toxicity both in effluent discharging tributaries and river. However, the genus, viz. *Anabaena, Arthrosira, Chlorella, Fragilaria, Frustulia, Melosira, Microcystis, Synedra, Scenedesmus, Volvox* and *Zygnema* were almost absent at highly polluted sites. Among the zooplankton, *Brachionus* and *Polyarthra* were absent in all the tributaries while showed there presence in the river water significantly. *Keratella, Cyclops, Monnstyla* and *Filinia* showed their existence according to the severity of metal pollution at different sites.
Metal toxicity in plankton showed considerable variations due to variable discharges of un-treated industrial and sewage wastes into the river through different tributaries. The uptake and accumulation of zinc in plankton was dependent positively and significantly on water temperature. However, increase in water hardness significantly increased the iron, manganese and nickel in plankton.

Key words: metal toxicity, planktonic productivity, regression, river Ravi

Introduction

Discharging of all sorts of highly obnoxious matter into freshwater is an affront to civilized values and damaging sustainability of environment. The problem of water pollution is acute in some countries than in others but is basically the same throughout the world. While pollution has always occurred, the scale and rate of water pollution in the last few decades is greater than in the past because of rapid industrialization and urbanization.

Tremendously increasing population and establishment of industries in the urban areas results in the discharge of heavy metals, sewage effluents and their compounds into the rivers. In recent years, due to awareness about pollution, the programs for monitoring and abatement of the river pollution including heavy metal pollution have been initiated in Pakistan (Javed and Hayat, 1995; 1996; 1998; 1999). The discharge of large amounts of heavy metals and their compounds into the riverine system of Pakistan in general and of the Punjab province in particular has adversely affected the freshwater fisheries. This points towards desperate need for assessing the problem and to develop methods for alleviating the ill-effects of the pollutants like zinc, iron, manganese, cadmium, lead and nickel because polluted water can cause paralysis, meningitis, cancer, sterility, schistosomiasis, poliomyelitis and filariasis in animals (Singh *et al.*, 1982).

Materials and Methods

The stretch of river Ravi i.e., from Shahdera to Baloki headworks was monitored at following 12 sampling stations for metal toxicity of plankton:

River Site Sampling Stations		Effluent discharging tributary sampling stations	
Shahdera bridge	(R1)	Farrukhabad nulla	(T1)
Baradarri	(R2)	Munshi hospital nulla	(T2)
Sharqpur	(R3)	Taj company nulla	(T3)
Thatta polian wala	(R4)	Bakar mandi nulla	(T4)
I/B Q.B. link canal and Baloki headworks	(R5)	Hudiara nulla	(T5)
Baloki headworks	(R6)	Degh fall	(T6)

Samples were collected on fortnightly basis for the period of one year i.e. from May 02, 1998 to April 30, 1999. For a single sample, nearly 50-60 liters of water was filtered through a plankton net having a pore width of about 10 micrometer. For determining the frequency and percentage of different groups and species of algae, the drop method of Venkateswarlu (1969) was adopted. In case of benthic algae number of individuals under high power field of the microscope was recorded and density of different groups calculated.

The metal concentrations in plankton samples were determined on dry weight basis. Dry samples of planktonic biomass were digested in perchloric and nitric acids. Zinc, iron, manganese, lead, and nickel concentrations in plankton were determined through atomic absorption spectrophotometer by following the method Nos. 3500-Zn B, 3500-Fe B, 3500-Mn B, 3500-Pb B, 3500-Ni B respectively (S.M.E.W.W., 1989). Water temperature, dissolved oxygen, pH and electrical conductivity were determined through meters, viz. HANNA HI-8053, HI-9143, HI-8520 and HI-8733 respectively. However, total hardness was determined through the method described in S.M.E.W.W. (1989). Data were analyzed by following Steel and Torrie (1986) through analysis of variance and Duncan's multiple range test. Correlation and regression analyses were performed to find-out relationships / trends among various parameters under study.

Results

Metal toxicity in plankton: Plankton at Hudiara nulla showed significantly higher zinc content followed by that at Taj company nulla and Farrukhabad nulla. However, the difference between Taj company and Furrukhabad nullas was non-significant. The river at Sharqpur had significantly higher mean zinc concentration of 141.80 ± 11.25 $\mu g\ g^{-1}$ than rest of the river stretch. However, the mean annual planktonic zinc at Baloki headworks was significantly higher than at Shahdera bridge. The plankton samples collected from Farrukhabad nulla showed significantly higher mean iron content of 7351.00 ± 194.65 μg g-1. Degh fall had significantly minimum planktonic iron. In the river, Thatta polian wala presented the most iron polluted planktonic mass (Table 1). Plankton collected from Furrukhabad nulla, Taj company nulla and Hudiara had the maximum metal, however, the differences among these tributaries were statistically non-significant. Thatta polian wala showed

Table 1: Metal Concentrations (μg g-1 ± SD) in plankton

Effluent discharging tributary sampling stations		River site sampling stations	
Zinc			
Farrukhabad Nulla	199.10±22.54b	Shahdera bridge	82.96±13.28c
Munshi Hosp.Nulla	142.20±4.82d	Baradarri	85.75±10.10c
Taj Company Nulla	199.90±6.81b	Sharqpur	141.80±11.25a
Bakar Mandi Nulla	191.60±14.25c	Thatta polian wala	79.52±4.81d
Hudiara Nulla	206.00±4.85a	I/b Q.B. canal and Baloki Head works	62.67±3.77e
Degh fall	129.80±9.64e	Head Baloki	102.67±5.20b
Means Tributary water:	178.10±33.16a	River water:	92.56±27.31b
Iron			
Farrukhabad Nulla	7351.00±194.65a	Shahdera bridge	1874.66±48.62f
Munshi Hosp.Nulla	4592.50±50.21b	Baradarri	4893.28±160.20d
Taj Company Nulla	3505.38±30.94c	Sharqpur	5277.20±94.37c
Bakar Mandi Nulla	3083.42±28.52d	Thatta polian wala	5820.54±82.30a
Hudiara Nulla	2995.54±90.11e	I/b Q.B. canal and Baloki Head works	5439.38±43.01b
Degh fall	2300.55±35.92f	Head Baloki	4712.09±54.38e
Means: Tributary water:	3971.40±1819.73a	River water:	4669.52±1424.77b
Manganese			
Farrukhabad Nulla	681.20±30.22a	Shahdera bridge	220.50±10.35c
Munshi Hosp.Nulla	746.40±40.58a	Baradarri	240.80±12.55c
Taj Company Nulla	703.20±34.93a	Sharqpur	474.80±32.78a
Bakar Mandi Nulla	439.30±32.11b	Thatta polian wala	482.60±21.21a
Hudiara Nulla	741.90±40.53a	I/b Q.B. canal and Baloki Head works	391.90±24.54b
Degh fall	281.50±13.94c	Head Baloki	257.70±14.99c
Means: Tributary water:	598.92±192.91a	River water:	344.72±119.97b
Lead			
Farrukhabad Nulla	11.18±4.05a	Shahdera bridge	5.74±1.37b
Munshi Hosp.Nulla	6.83±1.04c	Baradarri	4.21±2.01e
Taj Company Nulla	4.05±1.21f	Sharqpur	9.55±3.94a
Bakar Mandi Nulla	5.33±1.73e	Thatta polian wala	4.71±0.72d
Hudiara Nulla	7.37±2.54b	I/b Q.B. canal and Baloki Head works	5.03±0.58c
Degh fall	5.91±1.14d	Head Baloki	4.01±0.42f
Means: Tributary water:	6.78±2.45a	River water:	5.56±2.04b
Nickel (μg g-1±SD)			
Farrukhabad Nulla	14.97±1.94b	Shahdera bridge	5.29±0.94e
Munshi Hosp.Nulla	8.31±2.34e	Baradarri	6.10±0.35d
Taj Company Nulla	10.26±4.21d	Sharqpur	9.24±3.01a
Bakar Mandi Nulla	10.97±3.61c	Thatta polian wala	8.47±2.11b
Hudiara Nulla	15.95±6.11a	I/b Q.B. canal and Baloki Head works	6.86±0.87c
Degh fall	8.06±1.38e	Head Baloki	6.79±0.32c
Means: Tributary water:	11.42±3.33a	River water:	7.12±1.47b

Table 2: Accmulation of metals in plankton depending upon physico-chemistry of water

Regression Equation			r/MR	R^2
Zinc in plankton	=	-278.87-10.62(DO) + 17.34 (W.Temp.)	0.8422	0.7093
SE	=	3.79** 9.19*		
Iron in plankton	=	No variable meet criteria.		
Manganese in plankton	=	957.98+1.59 (Hard.)-115.69(pH)	0.8838	0.7812
SE	=	0.01** 8.35**		
Lead in plankton	=	7.76-0.37(DO)	-0.4386	0.1924
SE	=	0.16*		
Nickel in plankton	=	1.41±0.03 (Hard.)	0.8648	0.7478
SE		0.003**		

* = significant at $p<0.05$, ** = signigicant at $p<0.01$, DO = dissolved oxygen, W. Temp. = water temperature, Hard = total hardness

maximum planktonic manganese while significantly minimum at Shahdera. Mean planktonic lead concentration was the highest at Farrukhabad nulla as 11.18±4.05 μg g-1 while among river site sampling stations the highest and lowest mean lead concentrations in plankton were recorded as 9.55±3.94 and 4.01±0.42 μg g-1 at Sharqpur and Baloki headworks respectively. Plankton collected from Hudiara showed the highest mean nickel content of 15.95±6.11 μg g-1 while the lowest at Degh fall. The river at Sharqpur presented the highest metal concentration in planktonic mass. Plankton at Baloki headworks showed significantly higher metal than at Shahdera.

Relationships between metal toxicity of plankton and physico-chemical variables: Table 2 shows the final step equations for the regression of metal ion toxicity of plankton on physico-chemical variables. The accumulation of zinc in plankton was dependent positively upon water temperature. Dissolved oxygen showed negatively significant regression on planktonic zinc. Total hardness and pH were the two water quality variables which showed 78.12% contribution towards manganese uptake by the plankton. The partial regression coefficient for hardness of water was positive while for pH was negatively significant. Lead accumulation in plankton was negatively correlated with dissolved oxygen. However, the equation computed for this relationship explains 19.24% variations in planktonic lead only. Total hardness appeared to be a variable that was responsible for about 74.78% towards accumulation of nickel in plankton. The regression coefficient for this variable was positive and significant at $P < 0.01$.

Planktonic productivity: Among phytoplankton, *Aphanocapsa, Bacillaria, Closterium, Cyclotella, Cocconeis, Cosmarium, Denticulla, Dinobryon, Euglena, Gloeocapsa, Pinnularia, Spirulina* and *Spirogyra* showed considerable tolerance against heavy metals toxicity both in tributaries and river. However, the genus, viz. *Anabaena, Arthrosira, Chlorella, Fragilaria, Frustulia, Melosira, Microcystis, Synedra, Scenedesmus, Volvox* and *Zygnema* were almost absent at highly polluted sites. Among the zooplankton, *Brachionus* and *Polyarthra* were absent in all the tributaries while showed presence in the river significantly. *Keratella, Cyclops, Monnstyla* and *Filinia* were the sensitive forms that showed their densities according to the severity of pollution at different sites.

Discussion

The uptake and accumulations of zinc in plankton were dependent positively and significantly on water temperature. There is no single pattern for effects of temperature on toxicity of pollutants to aquatic organisms. Temperature change in a given direction may increase or decrease toxicity, depending on the toxicant and species (Macleod and Pessah, 1993; Oanh *et al.*, 1995). Zinc would be more lethal to a poikilothermic animal at high temperature (Hodson and Spargue, 1995). An important modifying factor in an aquatic habitat is temperature that affect ionization also. Lloyd (1961) showed a 2.5 fold increase in toxicity for an increase in temperature from 7 to 20°C. Dissolved oxygen and pH appeared as the variables that showed negative regression on the accumulation of metals in plankton. Stiff (1971) reported that lethal concentrations of toxic forms of copper were 200-2000 times higher at pH 5 than at pH 9, depending upon the hardness of water. It may be considered that unusual combination of pH, alkalinity and hardness, perhaps brought about by acid or alkaline pollution, will change to the more usual combinations, given some time and the natural aeration that takes place in surface waters. Davies *et al.* (1976) found great differences in the toxicity of lead between soft and hard water when the metal was measured as total concentration. However, during this investigation the higher water hardness significantly increased the manganese in plankton. It might be expected that stresses on aquatic organisms caused by a reduction in ambient dissolved oxygen would greatly increase the toxicity of a pollutant in the water. Lloyd (1961) showed increase in lethality of copper, lead, zinc and phenols in relation to degree of de-oxygenation. He *et al.* (1998) reported that water and sediment pollution had profound effect on the aquatic ecosystem due to the discharges of metal bearing effluents in to the river.

Suspended matter and soluble metals affected the quality and quantity of the plankton in both tributaries and river. All the tributaries showed significantly lesser densities of both flora and fauna throughout the year. The streams carrying very high levels of heavy metals often have markedly reduced flora (Say and Whitton, 1981; Javed and Hayat, 1996). Metelev *et al.* (1971) observed that the ferric hydroxide deposition on the phytolplankton reduces the rate of photosynthesis and propagation. Among phytoplankton, *Aphanocapsa, Bacillaria, Closterium, Cyclotella, Cocconeis, Cosmarium, Denticulla, Dinobryon, Euglena, Gloeocapsa, Pinnularia, Spirulina* and *Spirogyra* showed considerable tolerance against heavy metals toxicity both in tributaries and river. However, the genus, viz. *Anabaena, Arthrosira, Chlorella, Fragilaria, Frustulia, Melosira, Microcystis, Synedra, Scenedesmus, Volvox* and *Zygnema* were almost absent at highly polluted sites. Among the zooplankton, *Brachionus* and *Polyarthra* were absent in all the tributaries while occurred in the river water significantly. *Keratella, Cyclops, Monnstyla* and *Filinia* were the sensitive forms and showed their existence according to the severity of pollution at different sites. Palharya and Malvia (1988) reported *Spirulina, Nostoc, Oscillatoria* and *Anabaena* as dominant and resistant forms against heavy metal toxicity in river. However, Unni (1986) reported *Keratella, Tropica, Filinia* and *Polyarthra* as tolerant forms against heavy metal toxicity. Javed and Hayat (1996) reported that the phytoplankton genera, viz. *Aphanizomenon, Bacillaria, Closterium, Cyclopedia, Cocconeis, Cosmarium, Chrococus, Denticulla, Euglena, Spirulina, Spirogyra* and *Volvox* showed considerable tolerance against heavy metals toxicity. *Keratella* and *Filinia* appeared to be the tolerant genera against heavy metals toxicity while *Cyclops* and *Philodena* were found as the sensitive forms in the river Ravi aquatic ecosystem.

Acknowledgments

This research was supported by a grant (P-AU/Env. 44) received from the Pakistan Science Foundation, Islamabad.

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