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Research Article
Seasonal Assessment of Heavy Metal Pollution in Water and Sediment of Fish Pond at Bhagwanpur, Roorkee (U.K.), India

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Abstract

Background and Objective: Heavy metals are one of the most common environmental pollutants and their presence in an aquatic ecosystem has become a major global environmental problems. The pond in Bhagwanpur region is used for polyculture of major carps. Rapid industrialization, sewage discharge, agricultural runoff and dumping of waste materials are challenges that Bhagwanpur fish pond is facing. The present research was aimed to study the seasonal distribution of some heavy metals (Copper (Cu), Chromium (Cr), Lead (Pb), Nickel (Ni) and Zinc (Zn)) in water and sediment samples collected from Bhagwanpur fish pond. **Materials and Methods:** The samples were collected for all four seasons from March, 2012 to February, 2014. After acid digestion, the samples of water and sediment were analyzed for levels of heavy metals using the Atomic Absorption Spectrophotometer. Data obtained were analyzed using one-way ANOVA and correlation coefficient. **Results:** Data collected for Cr (0.277 ppm), Pb (0.142 ppm) and Ni (0.187 ppm) in water was higher than the permissible limit of World Health Organization (WHO), Environmental Protection Agency (EPA) and United States Environmental Protection Agency (USEPA). The statistical analysis (ANOVA) reveals a significant effect of season on all metal in sediment except Ni ($p = 0.503$). However, in water, only Zn ($p = 0.014$) showed a statistically significant seasonal variation. Correlation coefficient value indicates a positive relationship between metal concentration within water and sediment. The concentrations of Cu (63.49 μg g^{-1}), Cr (48.74 μg g^{-1}) and Pb (104.41 μg g^{-1}) in sediment were higher than Threshold Effect Concentration (TEC) level recommended by Sediment Quality Guidelines. The highest concentration of metals in water was recorded in summer and lowest in spring, while in sediment metal concentrations was higher in winter and lower in summer and autumn. **Conclusion:** The result revealed that there is a considerable need for better understanding so that the pond can be managed effectively and the findings from this investigation can serve as baseline environmental data for monitoring of heavy metals accumulation in the pond.

Key words: Water quality, seasonal assessment, fish pond, heavy metals, industrial effluents

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Aquaculture has been growing rapidly as it is considered as one of the most important sources of fish protein production. For quantitative and qualitative growth of fish, it is necessary to have a sufficient supply of good quality water for the construction of ponds[1,2]. Farmed fish provide a good and low-cost source of polyunsaturated fatty acids that could be beneficial for the cardiovascular health in humans. According to Tornero and Hanke[3], the concentration of several natural and man-made toxic substances is higher in farmed fish as compared to wild fish. There are some sources from which these water bodies are getting polluted through heavy metals. They may occur due to industrial, anthropogenic and agricultural wastes. Agricultural runoff contains high concentrations of different pesticides, fertilizers and heavy metals[4,5]. Heavy metals can affect the ecosystem through bioaccumulation and biomagnification process and are potentially toxic to the environment and human life[6]. Monitoring the concentration of heavy metals in water, sediment and aquatic fauna is important as levels of heavy metals in these matrices especially sediment gives vital information regarding the degree of pollution, sources of contamination and their distribution[7]. All metals are virtually toxic when present at a higher level than the tolerance limit. Bhagwanpur fish pond is used for polyculture of major carps. The quality of the pond has been degrading rapidly due to agriculture runoff, urban runoff, road runoff and pollution due to pharmaceutical industries. From the literature survey, no work has been carried out on the environmental quality of water and sediment of ponds in this region. There is a considerable need for better understanding of these water bodies so that they can be managed effectively.

This study was to monitor the levels of metals-copper (Cu), Chromium (Cr), Lead (Pb), Nickel (Ni) and Zinc (Zn) in water and sediment samples collected from Bhagwanpur fish pond and to evaluate the effect of season over the concentration of heavy metals in water and sediment.

MATERIALS AND METHODS

Study area: Bhagwanpur is a small town in Roorkee tehsil of Haridwar district in the state of Uttarakhand, India. It is 11 km far away from Roorkee city. Bhagwanpur is an industrial estate having many pharmaceutical and biotech industries[8]. For the present investigation, water and sediment samples were collected from the fish pond in Bhagwanpur region, used for polyculture of major carps. It is located at the latitude of 29°56' N and longitude of 77°48' E (Fig. 1). Water and sediment samples were collected for all four seasons (spring, summer, autumn and winter) throughout for two successive years (2012-2013 and 2013-2014).

Sampling and sample preparation: Triplicate water and sediment samples were collected at each point to form one composite sample. Water samples were collected in pre-clean acid wash plastic bottles and acidified with concentrated HNO_3 to pH less than 2.0, then stored at 4°C until analysis. Water samples (200 mL) volume were prepared using an acid mixture (HNO_3: $HClO_4$ = 9:4) according to

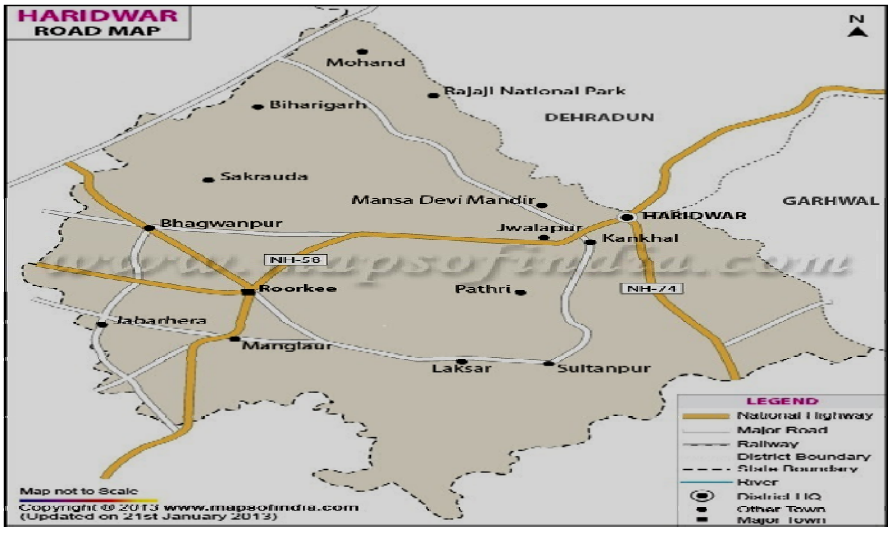

Fig.1: Map of the study area

Source: https://www.mapsofindia.com/maps/uttaranchal/roads/haridwar.htm

Aktar *et al.*[9]. The concentration of heavy metals was calculated by using following equation:

$$\text{Heavy metal concentration (ppm)} = \frac{\text{AAS reading} \times \text{diluted solution volume}}{\text{Volume of water sample}}$$

A steel pipe of 2 inches in diameter was pressed with pressure through the water column to obtain a sediment layer of about one foot. Each sample was then packed in separately acid soaked clear polythene packets and brought to the laboratory in ice buckets. The samples were dried in Petri dishes at 110°C for 24 h. To remove large particles, the dried sediment samples were passed through a 60 mesh stainless screen. About 0.5 g of sediment sample was weighed into a 100 mL beaker. The sediment samples were prepared by using concentrated HNO_3/HCl (1:3 v/v)[10]. The concentration of heavy metals was calculated by using following equation:

$$\text{Heavy metal concentration } (\mu g\ g^{-1}) = \frac{\text{AAS reading} \times \text{diluted solution volume}}{\text{Weight of sample (g)}}$$

All the samples were analyzed for 5 metals: Cu, Cr, Pb, Zn and Ni using Atomic Absorption Spectrophotometer (AAS) (GBC Scientific SensAA).

Statistical analysis: One-way ANOVA was used to evaluate the effect of the season on the heavy metal concentration in water and sediment. Correlation coefficient of variation was used to measure the strength of a linear relationship between heavy metal concentration in water and sediment. Differences were considered significant at p-value <0.05 and <0.01. Statistical analysis was carried out with SPSS14.

RESULTS AND DISCUSSION

Heavy metal in water: Seasonal metal concentration in water from Bhagwanpur fish pond was illustrated in Table 1 and its comparison with other global studies are shown in Table 2. The concentration of the analyzed heavy metals in water were in the order of Zn (0.356±0.082)>Cr (0.277±0.039)> Ni (0.187±0.090)>Pb(0.142±0.015)>Cu (0.122±0.016). The statistical analysis performed by one way ANOVA showed no significant seasonal variation (p>0.05) among Cu, Cr, Pb and Ni. However, the concentration of Zn showed a statistically significant seasonal variation (p<0.05). The highest concentrations of all the detected heavy metals were recorded in water during the summer season and lowest one was recorded in spring season (except Cu). The lowest concentration of Cu was recorded in autumn. This is in agreement with the findings of Bahnasawy *et al.*[11] and Ghannam *et al.*[12] who also studied the highest level of metals in water during summer, while lowest during winter. The high level of metals in water during summer may be due to the release of heavy metals from the sediments to the overlying water under the effect of both high temperature and a fermentation process resulting from the decomposition of organic matter[13]. Similar findings have been reported by Koffi *et al.*[14] who concluded that the high concentration of metals in summer season could be attributed to more bioaccumulation due to the metal concentration arising from reduced water level in this season. The result showed seasonal

Table 1: Seasonal variations of mean metal concentrations (ppm) in water from Baghwanpur fish pond from March, 2012 to February, 2014

Metals	Spring	Summer	Autumn	Winter	Mean±SD	F-value
Cu	0.114	0.146	0.113	0.118	0.122±0.016	0.309
Cr	0.240	0.330	0.282	0.258	0.277±0.039	5.034
Pb	0.129	0.163	0.143	0.135	0.142±0.015	0.065
Ni	0.114	0.300	0.219	0.117	0.187±0.090	0.876
Zn	0.257	0.445	0.394	0.330	0.356±0.082	14.043*

*Value is significant at the 0.05 level, SD: Standard deviation

Table 2: Concentration of heavy metals in water samples from Bhagwanpur fish pond and comparison with other literature mean (ppm)

Guideline/locality	Cu	Cr	Pb	Ni	Zn	References
WHO	2	0.05	0.05	0.02	-	WHO[24]
EPA	1.3	0.05	0.05	-	5.0	EPA[26]
EC	2	0.05	0.01	0.02	0.1	EC[25]
USEPA	1.0	-	0.05	-	1.0	USEPA.[23]
FAO	0.2	5.0	-	5.0		FAO[22]
Bagwanpur pond	0.122±0.016	0.277±0.039	0.142±0.015	0.187±0.090	0.356±0.086	Present study
Siberian pond	0.002	0.002	0.002	0.002	-	Gladyshev *et al.*[31]
Ponds of sundarban (India)	-	-	0.080-0.596	-	0.007-0.736	Kaviraj and Thakurta[32]
Palar river vaniyambadi segment	1.62-1.76	3.20-3.28	1.40-1.60	0.30-.045	2.50-3.05	Prabhahar *et al.*[33]
Fish farm in fayoum	0.026-0.05	-	0.04-0.101	-	0.043-0.115	Abdallah[34]

variation might be due to the fluctuation of the amount of agricultural drainage water, sewage effluents and industrial waste discharged into the water[15,16]. The seasonal variation of metals in water have been reported by different authors for different water bodies: Rajappan and Joseph[17] for the river, Benson *et al.*[18] and Sanka *et al.*[19] for estuaries, Bhat *et al.*[20] and Salem *et al.*[21] for pond. Comparison of mean concentration of the metals in the pond with the guideline values of Food and Agriculture Organization (FAO) [22], United States Environmental Protection Agency (USEPA)[23], World Health Organization (WHO)[24], European Commission (EC)[25], Environmental Protection Agency (EPA)[26] showed compliance with Cu, while Cr, Pb, Ni and Zn were recorded higher than their guideline values. The level of Zn in the water was highest followed by Cr, Ni, Pb and Cu. Abdel-Satar *et al.*[27] also attributed high concentration of Zn in their findings. Ibrahim and Omar[28] found that the accumulation and bioaccumulation factor of heavy metals especially Zn, Fe and Cu were higher in summer season due to an increase in temperature. Saeed[29] concluded that environmental factors as climate (seasonal variations and temperature) and drainage wastewater affect the physical and chemical characteristics of water as well as fish condition and quality. Comparing the data of this study with other water sources the result shows variation in metal concentration which may be due to seasonal variation and types of discharge[30].

Heavy metal in sediment: Table 3 and 4 shows the concentration of metal in sediment in different seasons and its comparison with other global studies. Mean metal concentration for sediment were found in the following order: Pb (104.41±24.61)>Zn (94.05±26.51)>Cu (63.49±17.35)> Cr (48.74±13.22)>Ni (19.69±6.37). All the metals (except Ni) showed a statistically significant seasonal variation (ANOVA, $p<0.05$). When compared to water, sediment contained a high concentration of metals, since the sediment act as a reservoir for all contaminants and dead organic matter descending from the ecosystem above. Similar findings were reported by other authors[35,36].

The result showed the highest concentration of Pb in sediment followed by Zn and Cu. The concentrations of Cu, Cr and Pb in sediment were recorded higher than TEC (Threshold Effect Concentration) recommended by the Sediment Quality Guidelines. Pb is a toxic substance and can produce the damaging effect on the kidney, liver, nervous system and other tissues[37,38]. Enrichment of Pb in the sediment might be the result of urban runoff after having been emitted by vehicles which are then deposited on roads and washed off by rainfall[39]. Zn and Cu are generally good indicators of anthropogenic inputs[40]. Zn and Cu have a tendency to couple with organic carbon, decomposition of the organic matter remains are found to release heavy metals back to the sediment[41]. To a great extent, an opposite manner of the seasonal distribution pattern of heavy metal in sediment and water was obtained. Similar findings were reported by Ali and Abdel-Satar[13]. Mzimela *et al.*[42] also attributed highest metal concentration in sediment during winter and the lowest during summer. Comparing our data with other published in Table 4 showed that different metal concentration ranges recorded may depend on the nature of region studied.

The Pearson's correlation between heavy metal concentration in water and sediment is shown in Table 5. The

Table 3: Seasonal variations of mean metal concentrations (μg/g dry wt.) in sediment from Bhagwanpur fish pond from March, 2012 to February, 2014

Metals	Spring	Summer	Autumn	Winter	Mean±SD	F-value
Cu	71.75	50.45	47.80	83.95	63.49±17.35	8.167*
Cr	57.85	37.50	37.30	62.30	48.74±13.22	7.618*
Pb	119.15	84.20	82.90	131.40	104.41±24.61	37.463*
Ni	20.90	16.40	13.40	28.05	19.69±6.37	0.933
Zn	98.10	74.30	73.80	130.00	94.05±26.51	21.774*

*Value is significant at the 0.05 level, SD: Standard deviation

Table 4: Concentration of heavy metals in sediment samples from Bhagwanpur fish pond and comparison with other literature mean (μg g^{-1} dry wt.)

Locality	Cu	Cr	Pb	Ni	Zn	References
LEL	16.0	26.0	31.0	16.0	120	NOAA[44]
TEC	31.6	43.4	35.8	22.7	-	NOAA[44]
PEC	149.0	111.0	128.0	48.6	-	NOAA[44]
SEL	110.0	110.0	250.0	75.0	820.0	NOAA[44]
Permissible limit	16-110	-	31-250	-	120-820	Persaud *et al.*[45]
Bagwanpur pond	63.49±17.3	48.7±13.2	104.4±24.6	19.6±6.37	94.05±26.5	Present study
El Max fish farm	38.36-48.77	-	27.240-46.46	-	86.625-331.38	El Zokm *et al.*[46]
Fish farms in fayoum	24.3-50.3	-	19.0-34.4	-	125-315	Aiyesanmi[43]
Western harbour and El-max bay	11.73-377.91	-	25.94-592	-	17.98-246.27	Pekey *et al.*[47]

LEL: Lowest effect level, TEC: Threshold effect concentration, PEC: Probable effect concentration, SEL: Severe effect level

Table 5: Correlation matrix between heavy metal concentration in water and sediment collected from Bhagwanpur pond from March, 2012 to February, 2014

	CuW	CrW	PbW	NiW	ZnW	CuS	CrS	PbS	NiS	ZnS
CuW	1									
CrW	0.634	1								
PbW	0.831*	0.540	1							
NiW	0.769*	0.878**	0.827*	1						
ZnW	0.349	0.838**	0.334	0.610	1					
CuS	0.141	-0.463	0.167	-0.230	-0.654	1				
CrS	0.130	-0.508	0.205	-0.238	-0.699	0.978**	1			
PbS	-0.053	-0.608	-0.038	-0.442	-0.734*	0.956**	0.964**	1		
NiS	0.570	-0.069	0.605	0.237	-0.316	0.859**	0.824*	0.690	1	
ZnS	-0.141	-0.607	-0.220	-0.578	-0.572	0.861**	0.809*	0.910**	0.585	1

*Correlation significant at the 0.05 level (2-tailed), **Correlation significant at the 0.05 level (2-tailed), CuW: Cu in water, CrW: Cr in water, PbW: Pb in water, NiW: Ni in water, ZnW: Zn in water, CuS: Cu in sediment, CrS: Cr in sediment, PbS: Pb in sediment, NiS: Ni in sediment, ZnS: Zn in sediment

correlation matrix showed a negative correlation between Pbs in sediment and Znw in water. No significant correlation was found in between metals in water and sediment. However, the results showed a significant positive correlation between some of the metals within water and sediment. This may be due to the existence of some metals in the same oxidation state reacting similarly to the aqueous environment or that the metals with high correlation coefficients exist together in a mineral and are co-leached into the aquatic system accordingly[43].

CONCLUSION AND RECOMMENDATION

The study concluded that concentration of Cr, Pb, Ni and Zn in water was higher than the permissible limit of WHO, EPA, EC and USEPA except Cu. The concentrations of Cu, Cr and Pb in sediment were higher than TEC according to Sediment Quality Guidelines. The water quality of Bhagwanpur pond is polluted as a result is above the permissible limits. The sewage discharge, agricultural runoff and continuous dumping of waste material especially sanitary waste are affecting the water quality. This pollution level has its bad effect on both of fauna and flora at the area and it can explain the poor quality of the pond fish species, so it is strongly recommended that strict vigilance and constant monitoring are needed to maintain the water quality of the pond.

SIGNIFICANCE STATEMENT

This study discovers seasonal variation in metal accumulations may be due to the fluctuation of the amount of agricultural drainage water, sewage effluents and industrial waste discharged into the pond water. The concentration of metals in water and sediment were higher than the permissible limits. The result revealed that there is a considerable need for better understanding, so that the pond can be managed effectively and the findings from this investigation can serve as baseline environmental data for monitoring of heavy metals accumulation in the pond.

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