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Heavy metal accumulation in some selected ponds of district Ludhiana (Punjab), India

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Abstract
In India, fresh water bodies particularly ponds form the lifeline of Indian villages. The present study was carried out to analyze various heavy metals in pond water of three different sites from July 2016 to March 2017 covering three annual seasons. The naturally occurring ponds of villages Kila Raipur and Lohatbaddi (Ludhiana) were selected as study sites while Fish Farm Complex in Guru Angad Dev Veterinary and Animal Sciences University (GADVASU) served as control site. Surface water samples were collected and analyzed for the presence of heavy metals by ICAP–AES. The results of heavy metal analysis indicated that Arsenic, Cadmium, Chromium, Copper, Manganese, Nickel, Lead and Zinc were primarily present in the water samples with concentration higher in the ponds of villages Lohatbaddi and Kila Raipur as compared to the control. This is a pointer of the high pollution load in these ponds as the water of these pond was recipient of solid waste, detergents and other chemicals from village households and the aquatic fauna was directly affected.

Keywords: Freshwater, heavy metals, pollution, pond water

1. Introduction

Freshwater bodies are highly dynamic ecological pockets and their water quality ensures the presence of a healthy food chain. Heavy metals are the environmental pollutants which are considered as the most problematic and hazardous of all environmental pollutants because these are non-biodegradable and have persistant properties that have very detrimental effect on fishes and human beings [1-3]. Heavy metals cause contaminations that result in a long lasting effect on the ecological balance of the environment and the density of the different aquatic species living in it [4-6]. The bioavailability of heavy metals largely depends upon the environmental conditions and it is the ionic state of metal which causes harm to the organisms [9].

In rural areas, the village ponds form the lifeline of the rural population as the people have a partial dependence upon these freshwater bodies for their entire water requirement such as domestic needs, irrigation, bathing and fishing [10]. The increased household wastewater outflow and discharge of the septic tanks, has inundated the village ponds leading to the worsening of water quality of these resources to an alarming extent [11, 12]. Therefore, there is a need to assess the concentrations of heavy metals in these village ponds which are heavily polluted by human interference and activities. The presence of heavy metals has been reported in Harike Wetland [13, 14]. Similarly, some heavy metals have also been reported in Sutlej River around Ludhiana [15]. Thus, this study aimed to investigate the concentration of heavy metals in pond water, so that the villagers, which use this pond water for fish culture, be made aware of water quality to achieve the maximum yield in good culture practices.

2. Material and methods

2.1 Study area

The villages Lohatbaddi and Kila Raipur are located 39 KM and 17 KM towards South from District head quarters Ludhiana, respectively (Fig. 1). The selected pond of village Lohatbaddi is surrounded by agriculture fields while the pond of Kila Raipur village is surrounded on three sides by agriculture fields and on one side by the village houses. Both the ponds are reservoir of agricultural runoff and domestic wastes from the village houses and cattleyards.

Fig 1: Sites for collection of water sample: **a.** Fish farm at GADVASU b. Lohatbaddi c. Kila Raipur

2.1 Collection of water samples
Water samples were collected in triplicate in acid washed polythene bottles. A total of 9 water samples were collected once in a season from different sampling sites of district Ludhiana. Water sampling was carried out throughout the study period for three seasons during July 2016 (summer), December 2016 (winter) and March 2017 (spring).

2.2 Digestion of water samples
Water samples from all the selected locations were analyzed for the presence of heavy metals. To 10 ml of each water sample 10 ml of diacid (70 ml of Nitric acid + 30 ml of Perchloric acid) was added and left for overnight digestion. Then the samples were placed on hot plate at 250ºC until the sample became colourless with reducing of its volume to 1-3 ml. The digested samples were cooled, diluted and made the final volume 25 ml with distilled water in standard flask. The sample solution was filtered using Whatman filter paper no. 42 [16].

2.3 Elemental analysis of digested water samples
The processed samples of water were analyzed for presence of heavy metals like Arsenic (As), Lead (Pb), Zinc (Zn), Copper (Cu) and Cadmium (Cd) by Inductively Coupled Argon Plasma Atomic Emission Spectroscopy (ICAP–AES).

2.4 Statistical Analysis
The data thus obtained was subjected to factorial CRV for detremining the significance of difference with respect to sites and different months. The statistical analysis was done by using CPCS I software.

3. Results and discussion
Maximum concentration of heavy metals were observed in water samples collected from the village pond of Lohatbaddi followed by Kila Raipur as they presumably carried high pollution load due to runoffs from human activities in the villages. Various heavy metals recorded at different sites during various seasons are shown in Table 1.

3.1 Arsenic (As)
In the present study, the values of arsenic ranged from 0.003mg/l to 0.008mg/l at GADVASU, from 0.004mg/l to 0.015mg/l at Lohatbaddi and from 0.005mg/l to 0.009mg/l at Kila Raipur which were found to be within the permissible limit (0.05 mg/L) as designated by WHO [17]. However, among the various seasons, highest values were observed in summer and winter and lowest in spring in the water samples from all the three sites. The possible reason of presence of arsenic in these water bodies might be leaching from soil and agricultural runoff as arsenic is used in many herbicides [25].
The overall arsenic content in water ranged from 0.003mg/l to 0.015mg/l which is further supported by Jang *et al* [18] and Benneyworth *et al* [19], who too recorded the similar range of arsenic from 0.017mg/l to 0.188mg/l and from 0.014mg/l to 0.017mg/l in the water of aquaculture ponds situated in the coastal region of Chianan plain (Taiwan) and the ponds situated in Khulna and Upazila districts of Bangladesh, respectively. However, Alam and Rahman (2010) estimated relatively lower range (0.001-0.004mg/l) of arsenic in the pond water of Gournadi and Pathorghata of Barishal district and Barguna district, respectively in Bangladesh.

3.2 Cadmium (Cd)
The range of Cd was 0 to 0.002mg/l at GADAVSU, 0 to 0.004mg/l at Lohatbaddi and 0 to 0.003mg/l at Kila Raipur which was within the permissible limits prescribed by WHO [17] i.e., 0.01mg/l thereby indicating that it was suitable for aquaculture and irrigation purposes. Seasonally, the concentration of Cd was higher in summer at all the sites and no cadmium was detected in the spring season indicating that the various sources of cadmium like industrial effluents that can contaminate the water are lacking in the rural settings. Similar range of cadmium from 0 – 0.003 mg/l was recorded by Toor *et al* [11] in seventy-eight pond water samples collected from Mangat, Dehlon, Pakhowal, and Sudhar blocks of district Ludhiana which was also within the safe limits. They concluded that due to the lower levels of cadmium in the water samples, these water bodies could not result in direct hazard as there was no industrial activity in the immediate locality of the study area.
Cadmium is highly toxic metal that can disrupt a number of biological systems, usually at lower doses that are much lower than most toxic metals [20]. The highest value of cadmium in the present investigation was recorded at Lohatbaddi (0.004mg/l) as compared to GADVASU and Kila Raipur which might be due to the use of cadmium containing fertilizer, agricultural chemicals, pesticides and sewage sludge in farm land [21] and also due to the leaching of Cd that means high mobility of Cd because of its weak binding to soil and sediments [22, 23].

3.3 Chromium (Cr)
The values of chromium concentration in water varied from 0.003mg/l to 0.023mg/l at GADVASU, from 0.012mg/l to 0.062mg/l at Lohatbaddi and from 0.007mg/l to 0.030mg/l at Kila Raipur.
The level of chromium during this study was found to be within the permissible limits (0.05mg/l) prescribed by WHO [17] at all the sampling sites except Lohatbaddi where the value of chromium (0.062 mg/l) exceeded the maximum permissible limit during summer. Similar range of chromium content i.e., 0.014 to 0.043mg/l was recorded by Mastan [24] in the water of Kolleru Lake situated in Andhra Pradesh. However, Sajal and Tiwari [10] observed relatively higher concentration of chromium (0.52 to 0.818mg/l) in the ponds of Raipur city situated in Chhattisgarh (India). The high content of chromium in these water samples might be due to various anthropogenic activities, industrial and textile effluents, tanneries and household sewages [21, 25].

Table 1: Seasonal variations in various heavy metals (mg/L) at three sampling sites.

Seasons	Metals / Sites	Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Manganese (Mn)	Nickel (Ni)	Lead (Pb)	Zinc (Zn)
Summer	GADVASU	0.008±0.00	0.002±0.00	0.023±0.00	0.036±0.00	0.179±0.01	0.022±0.00	0.052±0.00	0.138±0.02
	Lohatbaddi	0.015±0.00	0.004±0.00	0.062±0.02	0.042±0.01	0.186±0.01	0.024±0.00	0.154±0.05	0.457±0.08
	Kila Raipur	0.009±0.00	0.003±0.00	0.030±0.00	0.038±0.01	0.193±0.02	0.026±0.00	0.111±0.01	0.476±0.14
Winter	GADVASU	0.007±0.00	0.002±0.00	0.021±0.00	0.017±0.00	0.141±0.01	0.014±0.00	0.051±0.01	0.104±0.01
	Lohatbaddi	0.015±0.00	0.002±0.00	0.045±0.01	0.034±0.01	0.180±0.00	0.025±0.00	0.072±0.00	0.090±0.01
	Kila Raipur	0.008±0.00	0.003±0.00	0.023±0.00	0.024±0.00	0.204±0.00	0.026±0.00	0.136±0.01	0.448±0.05
Spring	GADVASU	0.003±0.00	ND	0.003±0.00	0.038±0.01	0.045±0.00	0.003±0.00	0.014±0.01	0.038±0.00
	Lohatbaddi	0.004±0.00	ND	0.012±0.00	0.069±0.06	0.050±0.00	0.004±0.00	0.009±0.00	0.035±0.01
	Kila Raipur	0.005±0.00	ND	0.007±0.00	0.048±0.02	0.097±0.00	0.005±0.00	0.016±0.00	0.039±0.00
WHO permissible limit	--	0.05	0.01	0.05	2.0	0.3	0.07	0.05	5.0

ND- Not detected.

3.4 Copper (Cu)

The values of copper content in water varied non-significantly from 0.024mg/l to 0.048mg/l at GADVASU, from 0.017mg/l to 0.069mg/l at Lohatbaddi and from 0.034mg/l to 0.0381mg/l at Kila Raipur which were within the permissible limits (2mg/l) established by WHO [17]. The overall copper content at all sampling sites during the study period, therefore, ranged from 0.017 mg/l to 0.069 mg/l which was in accordance with Plessis [28] and Rahman *et al* [29], who too recorded the similar range of copper from 0.01 to 0.07mg/l and 0.002 to 0.01mg/l in Omatako dam and Von Bach dam in Namibia and Balu and Brahmaputra rivers in Bangladesh, respectively. A comparatively higher concentration of copper i.e. from 0.044 to 0.887 mg/l was observed in the water samples collected from the Nile Tilapia farms in Egypt [30].

Copper, being a key constituent of metabolic enzymes, is an essential micronutrient for cellular metabolism in living organisms [26]. However the higher concentrations of copper can be extremely toxic to intracellular mechanisms in aquatic animals [27]. It was quite apparent from the data that during the study period the highest concentration of copper was found to be in the pond water of Lohatbaddi in all the seasons which might be due to the agricultural runoff as copper sulphate ($CuSO_4$) was often used as an algaecide in commercial and recreational fish ponds to control the growth of phytoplankton and filamentous algae and also to control certain fish disease which is documented early by Boyd [31].

3.5 Manganese (Mn)

The values of manganese ranged from 0.045mg/l to 0.179mg/l at GADVASU, from 0.050mg/l to 0.186mg/l at Lohatbaddi and from 0.097mg/l to 0.204mg/l at Kila Raipur which were within the safe limits (0.3mg/l) as prescribed by WHO [17].

The results varied significantly ($P<0.05$) across different seasons whereas non-significantly ($P>0.05$) across different sites. The seasonal variation in manganese at different sampling sites during the study period. The overall manganese content at all sampling sites during the study period ranged from 0.045mg/l to 0.204mg/l which is further supported by Osman *et al* [22] and Sajal and Tiwari [10] as they too observed the similar range of manganese i.e. 0.08 - 0.145 mg/l and 0.016 - 0.183 mg/l in water samples collected from El-Serw Fish Farm (Egypt) and ponds of Raipur city (Chhattisgarh, India), respectively.

Recently, Nzeve [32] has recorded the similar range of manganese i.e. from 0.006mg/L to 0.146mg/L in the water samples collected from Masinga Reservoir (Kenya) and concluded that the surface water of Masinga reservoir is fit for human consumption as the values of manganese were within the safe limits recommended by WHO [17]. The highest concentration of manganese was recorded at Kila Raipur during the study period which might be due to the leaching of manganese from the soil and rock into the ground and surface water [10].

3.6 Nickel (Ni)

The values of nickel have been recorded between the range of 0.003mg/l to 0.026mg/l which were lower than the permissible limit of (0.07 mg/l) set up by WHO [17]. The results of the present study are supported by the findings of Rahman *et al* [29] who recorded a similar range of nickel content (0.040 to 0.047 mg/l) in the water samples collected from Balu and Brahmaputra rivers (Bangladesh). However, Singh *et al* [33] observed slightly higher concentration of nickel i.e., 0.02 to 0.08 mg/l in the treated waste water discharged from Dinapur sewage treatment plant (DSTP) situated in Varanasi (India).

Highest levels of nickel were reported in the village pond of Kila Raipur which may be attributed to higher pollution load at the site due to the discharge of domestic sewage, agricultural runoff and washing of vehicles. Although nickel is a non-toxic element, yet higher concentration of it affects physiological processes of humans as well as aquatic flora and fauna [34]. The high level of nickel reported in water samples may due to mixing of variety of wastes including that of automobile repair shops, trash incinerators, sewage and agricultural runoff [35].

3.7 Lead (Pb)

Lead is a persistent heavy metal which has been characterized as a priority hazardous substance [36] and levels of lead varied significantly at different sampling sites during different seasons. The maximum permissible concentration of lead is 0.05 mg/l WHO [17], according to which at the sites Lohatbaddi and Kila Raipur was found to be above the permissible limits, whereas in fish farm at GADVASU it was found almost within the desirable limits. Similar elevated levels of lead with average concentration of 0.33mg/l and 0.05 mg/l was observed in water samples collected from Azuabie Creek (Port Harcourt) and Tiga dam (Nigeria) by Abalaka [37] and Ekweozor *et al* [38], respectively. Lead contamination of these surface waters might be the result of entry from old plumbing, household sewages, agricultural runoff carrying lead containing pesticides and phosphate fertilizers, fallout of lead dust and human and animal excreta [39].

3.8 Zinc (Zn)

During the present investigation, the values of zinc have been found to be in the range of 0.035 to 0.476 mg/l which was within the permissible limit of 5.00 mg/l as prescribed by WHO [17]. This shows that zinc toxicity is absent in the study area. Similar levels of zinc i.e. 0.002 – 0.076 mg/l were observed by Venkatesh [40] in the water samples collected from ponds of Bhadra fish farm in Karnataka (India). Zinc, being involved in nucleic acid synthesis, is an essential trace element and micronutrient in living organisms, found almost in every cell [36].

During the study period at all sampling sites of district Ludhiana the concentration of heavy metals in water followed the order: Zn > Cr > Mn > Pb > Cu > Ni > As > Cd, thereby depicting that Zn was detected in the highest concentration of all the heavy metals identified whereas Cd exhibited the lowest concentration in the water samples. This sequence of heavy metals in water samples from village ponds resembles the order presented by Brraich and Jangu [13]. They observed the order of heavy metals as Zn > Pb > Cu > Cr > Mn > Ni > Cd in the water samples from Harike wetland indicating the highest concentration of heavy metal in natural water samples of Zn and lowest of Cd.

Conclusion

The heavy metal analysis of water samples during the present study revealed that the concentration of As, Cd, Cu, Mn, Ni, Pb and Zn were within the permissible limits established by WHO [16] at all the sites whereas Cr concenration in water samples was beyond the permissible limits at Lohatbaddi which probably due to the pollution of these ponds by agricultural runoff, dumping of solid waste and soil erosion. Thus, it could be considered to be effective management tools for protecting and remediating aquatic environment. The differences are site specific but depending on the pollutants they affect as toxins to all life forms in water bodies and may also lead to health deterioration effects upon human consumption.

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