METAL POLLUTION IN PAKISTANI LAKES. A REVIEW

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ABSTRACT: *Accumulation of heavy metals in freshwater ecosystems is a global issue. This review investigates level of heavy metal pollutants in the lakes studied so far in Pakistan. The Lakes include Rawal, Namal, Kallar kahar, Manchar, Keenjhar, Khanpur and Mangla. The heavy metals may be present in lake water as well as sediment. The concentration of metals was greater in sediments than water as metal pollutants dilute in water however the aquatic environment of a lake is responsible for the level of metal concentration in sediment and water. The heavy metal concentrations measured for all the lakes were greater in sediment than in water. Namal and Manchar Lake has highest sediment concentrations for some metals in comparison to the rest of the lakes. Also the concentrations of metals in water for the lakes Kallar Kahar, Manchar and Mangla were found highest. The lake water has been compared with the three recommended guidelines namely World Health Organization (WHO), United States Environmental Protection Agency (USEPA) and Pakistan Environmental Protection Agency (Pak-EPA). Metals As, Cd, Cr, Ni and Pb has been found with higher concentrations than the recommended permissible limits for the various lake waters studied so far.This article not only gives a comprehensive assessment of heavy metal pollution level in lakes found in different areas of Pakistan but also provides a reference for the improvement. The study highlights that a small number of Lakes in Pakistan have been analyzed so far for heavy metal pollution assessment. This reflects that there is an urgent need for sediment and water quality assessments in Pakistani Lakes.*

Key words: sediment, metal pollutants, permissible limits, Lake

INTRODUCTION:

Lakes are assets for a country contributing for drinking water, aquatic animal's habitats and a very good source of recreational activities for people of all ages. The size of a lake is greater than 20 acres and hence it is a larger body for inland water. Lakes as a source of freshwater reservoirs have been degraded in the past due to industrial waste, atmospheric deposition, mining and smelting activities, domestic effluent discharges, sewage treatment plants, agricultural fungicide, boating activities etc. The water of a lake is polluted when contaminants enter into it and either this contamination get dissolved in water or remain suspended in water or goes to the bed of the water body. In this way water quality of the ecosystems gets disturbed. Heavy metals in Ecosystem have drawn remarkable attention owing to their toxicity as well as accumulation into the aquatic biota [1, 4]. Lakes in the form of ecosystems ultimately accumulate heavy metals in sediment. Sediment is a significant indicator of heavy metal pollution in Lake Ecosystem. Sediment acts as a reservoir of toxic metals and is also a habitat for many living organism. Under favorable aquatic environmental conditions these metals may disperse back into lake water. The lake water physiochemical properties such as pH, redox potential, capacity of ion exchange, carbonate, organic carbon content etc., are responsible for the mobility of metals among the three phases namely aqueous, particulate and sediment[3]. The chemical toxic pollutants of concern in lakes include heavy metals like Arsenic, lead, cadmium etc. These pollutants cause adverse health effects in human as well as animals. High levels of toxic metals when adsorb in sediments, pose potential health risk as they transfer in the aquatic media. Uptake of metals by aquatic living organisms contributes to food chain [4]. Depending upon the aquatic environmental conditions sediment acts both as a source and a sink for the nutrients and heavy metals. Also sediment set trophic status of a lake as it act as carrier and at the same time a secondary-source of nutrients as well as heavy metals [4]. The heavy metals do not decompose and hence persists in the ecosystems. The metals persist in the cells of living organisms and hence are bio-accumulative, also known as persistent bio-accumulative toxic chemicals. Metals may enter the living organisms by all the three routes that are ingestion, inhalation and dermal absorption. Food is the major source heavy metal intake in the form of Lake Fish. A better understanding for lake water quality is the need of the hour by taking into account the sources of contamination [2].

So far few lakes have been examined for the heavy metal pollution levels in Pakistan. The lakes located into capital as well as provinces are given in Table 1. River Indus is the longest in Pakistan and provides water to many lakes present on its bank. Keenjhar is located on its bank in the Sind province of Pakistan. Keenjhar Lake is situated in Thatta. Keenjhar is the biggest manmade freshwater lake in Asia. It is 122 km from Karachi and 18 km from town of Thatta. It is a potential source of fisheries, wild life, picnic spot and irrigation. It is one of the major sources of water for the people of Karachi [Wikipedia, 1, 2]. Manchar Lake was created in 1930s at the time of construction of sukkur barrage on Indus River. The lake is fed by the canals Aral and Danister coming from river Indus. The lake has been a source of livings in the form of fish for many of the nearby villagers but due to environmental degradation people have to think alternate sources of livings. The saline water drained from the agricultural field of Balochistan is a source of contamination [Wikipedia]. Namal lake is an artificial shallow freshwater lake located in Mianwali. It is about 214 Km from capital city Islamabad. The lake is fed by a number of streams that drain from a surrounding hill. The lake has a wide catchment area for the collection of surface runoff. The average rain fall in lake area is 70-80 mm however it rains maximum in the month of July. The lake may be contaminated from the surrounding mining areas, recreational activities and nearby agricultural wastes. The lake is a habitat for a large number of migratory birds for different seasons [3]. Khanpur lake is located at about 40 km in northwest of Islamabad and is situated on the river Haro in Khanpur town with a total catchment area of 798 km^2. It provides drinking water as well as water for agricultural purposes for the twin cities of

Rawalpindi and Islamabad. The main sources of contaminants may include industrial and urban effluents, road and agricultural runoff, poultry farm wastes and release of pollutants from motorboats used for recreation [4].The Mangla lake is located about 100 km south-east of the capital city Islamabad in district Mirpur Azad Jammu and Kashmir. The lake is fed by Jhelum and Poonch the perennial rivers. Also the lake is fed by two non-perennial rivers Kanshi and Khad. The anthropogenic activities such as industrial, urban and agricultural wastes impart to the lake contamination. Natural processes such as atmospheric precipitation, erosion and weathering also contribute to the Lake pollution [5]. High sedimentation rates due to catchment erosion reduce the storage capacity of the Lake Mangla [5, 7]. Rawal Lake is located in an isolated section of village Malpur, Bani Galla and Margalla hills national park having an area of 8.8 km^2 and maximum depth of 31 m. The catchment area of the Rawal Lake is 275 km^2. Rawal Lake is an artificial reservoir fed by Korang River. Run offs enter the lake from four major and 43 small streams. Melted snow and natural water coming from Murree hills also become part of this lake. It provides water to the twin cities of Rawalpindi and Islamabad. Human population near catchment area, poultry waste, deforestation, soil erosion, agricultural activities and recreational activities are the sources of contaminants to this reservoir [6, 10]. Kallar Kahar Lake is located 135 km from Rawalpindi. This lake is shallow and salty. It is a beautiful picnic spot and has great attraction for migratory birds in winter season. Sewage is one of the major sources of contamination in the Lake [8].

Sampling:

Surface sediment samples as well as surface water samples were collected from the key points such as in the beginning points, middle points, end points and boating area points of a lake in different seasons. Sediment sampling points may be chosen with the help of global positioning system device (GPS). At certain cite (1 to 2 m^2) about three to five sub-samples were mixed to form a composite sample. A sampler (e.g. grab sampler) was used to collect Sediment at different depths ranges 0-10 cm, plastic spatula was also used to avoid contamination. Before the sediment samples were transferred to the pre-clean Ziploc labeled polythene plastic bags, the above water was decanted. The sediment samples were transported to the laboratory in large airtight containers. Large objects such as stones, parts of brick, concrete etc., are removed manually. The samples were then oven dried, grinded to fine powder, homogenized and sealed in pre-clean Ziploc labeled polythene plastic bags and stored in refrigerators for further processing [3, 4].The water sampling of a lake was accomplished by collecting a bulk water sample after combining three water samples of equal volume in an area of 10 to 20 m^2. Similarly a sufficient number of bulk water samples (100-150) were collected at the key sampling stations of a lake. The water samples so obtained were then filtered (0.45 µm) to remove any suspensions present. The filtered water samples were acidified with Nitric Acid (pH <2). The samples were then transferred to pre-cleaned labeled polyethylene bottles and stored in refrigerator until analysis [5].

MATERIAL AND METHODS:

The sediment samples collected from different lakes were subjected to chemical digestion procedure however water samples do not require digestion procedure. One gram of fine powdered sediment samples each were digested with the help of a digester (e.g. Temak-Digestor Model DK 20), under the action of Nitric acid, Hydrogen peroxide (30 %) and hydrochloric acid. The heated sample solution were allowed to cool and filtered through 0.45 micron filter paper. The volumes were made to 100 ml for each sample with the help of a volumetric flask, and transferred to high quality polyethylene bottles and stored at 4^oC. The heavy metals were analyzed using analytical techniques such as inductively coupled plasma-optical emission spectrometer (ICP-OES) and Flame atomic Absorption spectrometer (FAAS). However Flame Atomic Absorption spectrometer (FAAS) has been widely used for the determination of heavy metals in different lakes.

RESULTS AND DISCUSSIONS:

The concentration of heavy metals, in lake sediment as well as lake water, studied so far is given in the Table 3. In all the lakes mean values are given for the heavy metal concentrations except Keenjhar Lake whose ranges are given for different heavy metal concentrations. The review shows that Namal lake sediment has the highest concentrations for Cr while lowest for Cd and Pb. Manchar Lake sediment has highest concentrations for As, Cd and Zn in summer while lowest for As, Cr, Cu and Ni in winter. In another study of Manchar lake conducted from April to June the sediment concentration of Cu, Ni, Pb was found highest. Khanpur lake sediment has lowest concentrations for Zn in winter. Rawal lake water has the lowest concentration for As in autumn and lowest concentration for Zn in summer. Kallar Kahar lake water has highest concentrations for Cu and Zn in winter. Manchar lake water has highest concentration for As and Pb in summer while lowest for Cd and Ni in winter. Also the study of Manchar Lake conducted in April to June the concentration of Cr in water was found highest while that of Pb was lowest. The concentration of Cr and Cu was lowest in Keenjhar lake water. Mangla lake water has highest concentration of Cd for both summer and winter seasons while Ni was found highest in summer. The lake waters for the toxic pollutants are compared with the recommended drinking water standards as set by national and international authorities as given in Table 3. Manchar Lake has higher values of As for both summer and winter than the recommended WHO value. Also Rawal Lake has higher value of As in comparison to permissible limits as stated by WHO. In case of Cd all the lakes have values greater than WHO, USEPA and Pak EPA guidelines except Keenjhar Lake and Manchar Lake (winter) whose values are within the permissible limits of USEPA. All the lakes have Cr values below the USEPA permissible limits except Manchar Lake. Also the values of Cr are above the permissible limits of WHO and Pak EPA for all the lakes except Keenjhar lake and Rawal lake (summer). All the lakes reviewed for heavy metal pollutants in water so far have values well below than all the

guidelines provided for Cu except Kallar Kahar. Ni in all the lakes water has concentration values below the recommended permissible limits of USEPA. Also Ni values in Lake water of Keenjhar and Manchar (summer and winter) are below the WHO guidelines however all the lakes are found with higher Ni concentrations when compared with the Pak EPA. Pb concentrations in all the lakes water are found higher in comparison to WHO, USEPA and Pak EPA except Manchar Lake (April-June) with value within the permissible limits of Pak EPA. Zn in all lakes water is found within the recommended values of WHO, USEPA and Pak EPA.

Table 1: Brief Description of Pakistani Lakes.

Lakes	Creation and Type	Province/Capital	City	Surface Area (km^2)	Catchment Area (km^2)	Water Source	Maximum Depth	Water Type
Rawal	1962, Artificial	Islamabad	Margalla hills National park	8.8	275.2	Korang River	31 m	Freshwater
Namal	1913, Artificial	Punjab	Mianwali	4.8	420	Rain, local streams	2 m	Freshwater
Kallar Kahar	NA	Punjab	Chakwal	8	NA	Spring and hills runoff	5 feet	Salty water
Manchar	NA, Natural	Sind	Jamshoro	350	NA	Canals from river Indus	5 m	Freshwater
Keenjhar	NA	Sind	Thatha	134.7	NA	River Indus	7.9 m	Freshwater
Khanpur	1983	Khyber Pakhtunkhwa	Khanpur	18	798	Haro River	51 m	Freshwater
Mangla	1965, Artificial	Azad Jammu and Kashmir	Mirpur	251	33333	River Jhelum and Poonch	147 m	Freshwater

Table 2: Physio-Chemical properties of Sediment/Water in Pakistani lakes.

Name of lake	Season	Sample Type	EC (µS/cm)	TDS (mg/l)	pH	DO (mg/l)	CL^- (mg/l)	TA($CaCO_3$)	TOC (%)
Rawal	Summer	water	324	162	7.96	4.09	16.8	132	
	Winter	water	332	166	7.69	5.20	18.2	215	
Rawal			318	209	8.24	NA	NA	NA	
Namal	Year 2012		NA	NA	7.76	NA	NA	41.98	0.91
Kallar Kahar			NA	NA	NA	NA			
Manchar			6980–11030	3001.5-7536.9	7.90–8.34	3.5–7.4	869.0–1892.0	965.6–2095.3	NA
Keenjhar			NA	NA	NA	NA	NA	NA	
Khanpur	Summer		NA						
	Winter		NA						
Mangla	Summer		140	70	8.0	4.3	11	NA	
	Winter		250	125	7.8	4.4	8.8	NA	
Mangla	Winter, 2012		292.7	NA	7.79	NA	NA		
WHO,2008			1500	1000	6.5-8.5	-	200	-	

Table 3: Heavy metal concentrations in Lake Sediment (mg/kg) and Lake water (mg/l).

Name of lake	Season	Sample Type	Heavy metals							Reference
			As	Cd	Cr	Cu	Ni	Pb	Zn	
Namal	Year 2012	Sediment	13.8	1.4	75.6	28.6	57.3	12.4	90.9	[3]
Manchar	Summer 2005	Sediment	16.1	8.0	25.5	28.9	26.5	22.2	128.6	[12]
	Winter 2005	Sediment	12.8	6.94	16.3	18.0	19.7	17.1	78.2	
Manchar	April–June 2012	Sediment	NA	BD	28	42	91	137	95	[9]
Khanpur	Summer	Sediment	NA	1.88	34.66	36.84	NA	33.71	86.09	[4]
	Winter	Sediment	NA	2.457	37.65	28.05	NA	18.24	61.90	
Mangla	Winter, 2012	Sediment	NA	6.24	29.27	22.23	61.65	26.91	108.6	[7]
Rawal	Sep 2008	Water	0.04	NA	NA	NA	NA	NA	0.11	[6]
Rawal	Summer 2008	Water	NA	0.006	0.009	0.010	NA	0.162	0.014	[10]
	Winter 2008	Water	NA	0.025	0.097	0.017	NA	0.223	0.022	
Kallar Kahar	Dec 2001-Nov 2002	Water	NA	0.024	NA	0.258	0.117	0.118	1.412	[8]
Manchar	Summer 2005	Water	0.101	0.007	0.009	0.0231	0.0373	0.901	0.930	[12]
	Winter 2005	Water	0.073	0.004	0.008	0.0198	0.0338	0.089	0.750	
Manchar	April–June 2012	Water	NA	0.006	0.345	0.019	0.086	0.027	0.028	[9]
Keenjhar	Jan-Dec 2003	Water	NA	0.001 - 0.0043	0.00128 – 0.0049	00.0006 – 0.0073	0.00354 – 0.0395	NA	0.0014 – 0.1043	[1]
Mangla	Summer	Water	NA	0.03	0.08	0.02	0.13	0.38	0.03	[5]
	Winter	Water	NA	0.03	0.07	0.02	0.11	0.34	0.03	
WHO	Water		0.01	0.003	0.05	2.0	0.07	0.01	3.0	[10]**[5][**12]
USEPA	Water		0.01	0.005	0.1	1.3	0.7	0.015	5.0	[10][5]
Pak EPA	Water		0.05	0.001	0.05	2.0	0.02	0.05	5.0	[10][5]

CONCLUSIONS:

This is the first description of heavy metals review in Pakistani lakes which clearly reflects that more pollution assessment studies need to be done. Moreover Sediment need to be analyzed for heavy metal contents as it is the true indicator of a pollution level in the aquatic environment. The pollutants concentrations comparison with recommended guidelines showed the level of contamination in lake water. The element As has higher concentration for few lakes water in comparison to the recommended permissible limits. Most of the lakes water has higher concentrations for Cd, Cr, Ni and Pb than the permissible levels as stated by WHO, USEPA and Pak-EPA. There is only one lake water that is polluted with Cu however no lake water is polluted with Zn as per recommended guidelines. It is essential to take up a study for the investigation of the source that produces a particular contaminant in the lake water.

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