Review Article

A Review and Analysis of Heavy Metals in Freshwater Reservoirs of Pakistan: their Bioaccumulation, Biological Magnification and Biotic Transmission

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Abstract: (1) Water pollution is one of the most serious issues since both inorganic and organic wastes are released into the aquatic ecosystem. The release of waste into water channels enables heavy metal ions to enter the food chain, where they accumulate and move up the food chain. Therefore, higher trophic level animals are more susceptible to their toxicity. (2) This review has tried to provide a piece of detailed information about the biotic transmission of heavy metals in the food chain of important freshwater dams in Pakistan. (3) Rawal Dam, Mangla Dam, and Zabi Dam were identified as highly contaminated areas of freshwater that had detrimental effects on fish and human health. Changhoz and Ghol Dams have the healthiest ecosystems of all Pakistan's dams. Changhoz Dam's freshwater fish are considered to be safe for human consumption. Migratory birds at Rawal Dam collect heavy metals from consuming fish from freshwater reservoirs. Heavy metal pollution has been linked to a variety of social, ecological, and economic issues. (4) The detrimental effects of heavy metals on aquatic organisms and human well-being can be reduced if wastewater is purified before being released into freshwater.

Keywords: Rawal Dam, Mangla Dam, Changhoz Dam, Zabi Dam, Heavy metals, Fish, Migratory Birds

1. Introduction

Pakistan, located in South Asia, is blessed with breathtaking landscapes, majestic deserts, and many natural resources. Pakistan is largely dependent on its water supply for agricultural irrigation. Surprisingly, Pakistan has over 150 dams spanning all regions. Some of them are Mangla, Rawal, Changhoz, Shahpur, Ghol, Dharmalak, Zabi Dam. In addition to their practical uses as sources of energy and water (including drinking water, hydropower, irrigation, and fisheries), these dams also make for fabulous tourist destinations.

The Mangla Dam, at 33.12 N and 73.39 E in Mirpur, Azad Jammu, and Kashmir, and downstream in Jhelum, Punjab, Pakistan, has an elevation of 630 meters. Mangla Dam was built largely to improve the amount of water available from the Jhelum and its tributaries flow that could be used for irrigation. Its ability to produce electricity served as a supplementary purpose [1]. The Mangla Dam is suitable for wintering waterfowl and fish. The reservoir is essential for fish spawning and feeding. When the water level is high, a diversity of fish species are more prevalent. Mangla Dam breeds *Tor putitora,* a major freshwater game fish [2].

Rawal Dam is also an artificial reservoir that supplies water to Rawalpindi and Islamabad. Rawal Dam is located in Islamabad, across the Korang River, about 10 kilometers from Rawalpindi (at latitude 3342 N, longitude 7307 E, and an elevation of 1,800 m)[3]. There are plantations near the lake. The lake is used for both recreational and commercial fishing. In Rawal Lake, there are 11 genera and 15 different fish species. Doula (*Channa channa*), Rahu (*Labeorohita*), Thaila (*Catla catla*), Mori (*Cirrhinus mrigala*), Carp fish (*Cyprinus carpio*), and Tilapia (*Tilapia mossambica*) are among the fish species in Rawal Dam and its tributaries.

The Shahpur Dam (33° 37′ N 72° 41′ E), situated on the Nandana River in the Kala Chitta Mountain range in the Attock district of Punjab, Pakistan, is a hydroelectric dam. The Dam collects and distributes flood water for irrigation, drinking, and fish culture, among other uses[4, 5].

Dharmalak Dam is in Dharmalak, a populated area in Tehsil Lachi, Kohat KPK, Pakistan. The goal of dam development was to enable better irrigation and, last but not least, to cultivate fish [6]. Dharmalak Dam is home to seven known fish species, including *Ctenopharyngodon idella*, *Labeo rohita*, *Ompokpabda*, *Anguilla*, *Catla catla*, *Lepidocephalus guntea*, and *Cirrhinus mrigala* [7].

Karak, a region with a drinking water deficit, is situated 140 kilometers from Peshawar on the Indus Highway between Peshawar and Karachi at 33°7'12 North and 71°5' east. In the Karak district's productivity, abundance, and species composition, many tiny dams (Zabi and Changhoz) were built to hold rainwater for aquatic biota[8, 9]. The Changhoz River Dam was completed in 2007, about six kilometers west of Karak City in Khyber aquatic species. This Dam provides drinking water and irrigation [10]. Pakistani dam's precise location is depicted in Figure 1.

The physicochemical properties of an ecosystem's water and protected soil can support all aquatic biota. Land, soil, hydro melioration, and water are the region's agricultural sector's most important resources. Hydrobiont creatures devour wastewater. Heavy metals are among the most well-known and significant environmental hazards due to their toxicity to marine and terrestrial life. Non-biodegradability [10] is a hallmark of heavy metals. River runoff, atmospheric deposition, and anthropogenic activities all contribute to the introduction of heavy metals into the ocean. Anthropogenic poisons, in the form of heavy metals, have been increasingly washing into aquatic ecosystems over the past few decades. Thus, seaports and other coastal ecosystems with continual supplies include severely contaminated wastes. Heavy metals from sediments may affect biota. In review article it is reported that due to the large volume of untreated discharge of industrial and sewage water from urban centers and industrial fields, heavy metal contamination is substantial in the rivers of Ravi and Kabul. Therefore, the ecological status of both of these rivers is deteriorating. Some spots on the Chenab and Jhelum rivers have low to moderate metal contamination. The pollution level of the Indus River is significantly lower. Polluted river fish pose serious health risks to humans [11]. Similarly, this current review has tried to explain the major causes of heavy metal pollution in main freshwater reservoirs like the Rawal Dam, Mangla Dam, Zabi Dam, Changhoz, and Ghol Dams. It has also been tried to access how heavy metal pollution affects the freshwater, sediments, birds, and tissues of fishes for future research and reclamation of freshwater.

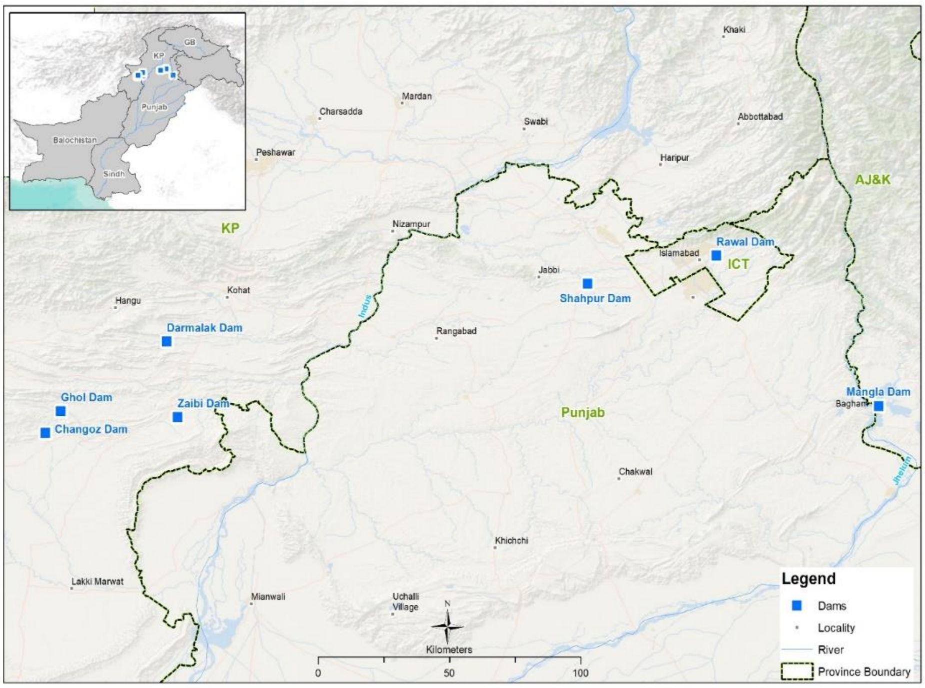


Figure 1: Map of dams in Pakistan

2. Heavy metal toxicity

Heavy metals are defined as "all naturally occurring metals with atomic numbers greater than 20 and elemental densities greater than 5 g/cm3"[11]. According to [12], "metals of natural or anthropogenic origin are pervasive in the aquatic environment, and it is therefore of great socio-economic importance to understand their behavior and interactions with aquatic life, especially fish, which are which are an important source of dietary protein that humans consumption."

Toxic heavy metal bio-accumulation in riverine ecosystem biota may harm animals and humans [12]. Heavy metals in biota can affect aquatic animal species' ecology and cause population declines. Heavy metals are neurotoxic to fish. Heavy metals' interaction with chemical stimuli may impair fish's ability to communicate [13]. Heavy metals can induce fish anomalies that impact survival, growth, well-being, and beauty. These fish deformities could indicate environmental heavy metal pollution [14]. Cadmium, lead, mercury, zinc, copper, nickel, cobalt, molybdenum, chromium, and tin are found most often in fish. Cadmium, copper, lead, zinc, mercury, and chromium are among the most frequently studied contaminants in terms of fish malformations.

Individual exposure to sub-lethal doses of heavy metals in birds may result in (1) reproductive failure, (2) increased vulnerability to disease, and (3) behavioral abnormalities [15]. At the population level, water pollution causes species to suffer significantly impaired harm and decline dramatically, even disappearing, followed by a shift in their distribution. Heavy metals have been found in studies to affect the reproduction and overall health of some birds [16, 17]. Contaminants like cadmium, mercury, and selenium have been demonstrated to harm birds' health by lowering their growth or body weight[18].

The toxicity of heavy metals and their potential for bio-accumulation in water, sediments, fish, and birds from different dams in Pakistan are reviewed in this article. Additionally, the accumulation of these metals and their effects on human health are discussed. The publication will be a helpful instructional tool for environmental sciences researchers and undergraduate and graduate students.

3. Heavy metals sources

The sources of heavy metals in the environment might be either human-caused, geogenic, or lithogenic. Heavy metals are released into the environment as a result of mining, industry, and agriculture. Ores are mined for these metals. Dry and wet deposition sends heavy metals used in mining, smelting, and other industrial processes back to the earth. Heavy metals are discharged into the environment via wastewater, including domestic sewage and industrial effluents. Heavy metals are also polluted by chemical fertilizers and fossil fuels.

Heavy metals come from fossil fuels used for transportation, heating, and industry. Vehicle traffic is a major source of Cr, Zn, Cd, and Pb [19]. Steel, textile, leather, and electroplating industries produce Cr [20]. Fertilizers also contain high Cr [21]. Nonferrous metal mining, especially Pb-Zn ore processing, is an anthropogenic source of Cd [22, 23]. Chemical fertilizer overuse also raises Cd levels [24]. Acid batteries, old plumbing, game bird hunting lead shot, and other sources discharge Pb into the environment. Leaded petrol combustion also pollutes Pb. Tetraethyl lead is still used in developing countries as an antiknock agent [22]. Mining, waste emissions, sewage sludge, fungicides, and agricultural fertilizers contribute copper to soil [1].

Human activities pollute rivers, lakes, and streams with heavy metals. Aquatic organisms are harmed when heavy metals contaminate freshwater bodies. Fish accumulate heavy metals due to their high trophic position [6].

Soil erosion in a Rawal dam sub-watershed has been analyzed by [25]. They predicted 19.13 t/ha soil loss annually. The catchment basin of Rawal Dam is home to an unplanned and chaotic human settlement [26]. Quaid-e-Azam University, Nurpur Shahan, Bani Gala, Bhara Kahu, Malpur, Diplomatic Enclave, and Ghora Gali are also damaging the dam through sedimentation and untreated residential waste. Agriculture occurs in the Rawal Dam's catchment area [27]. Farmers use pesticides and herbicides. Streams carrying excess irrigation water into Rawal Dam wipe away harmful pollutants. Rawal dams contain pesticide residues [28].

Weathering of Pir Panjal Range rocks and River Jhelum catchments increase heavy metal pollution in Mangla Dam. It's harming biodiversity, especially avifauna. When herbicides and pesticides run off farms, they harm aquatic life. Municipal pollution is rising and deposited in mounds surrounding the dam due to poor management. This waste is blown into the river, depleting oxygen and harming aquatic life. Sedimentation worries Mangla Dam. It's rising due to insufficient dam water. Rock weathering is another major contributor [2]. There are areas, a poultry farm, a mill, an oil processing business, and a stone factory all near the dam. Wastewater from surrounding corporations that was discharged directly into the dam without purification contained Pd as well as other targeted metals Cr, Cu, Fe, and Ni.

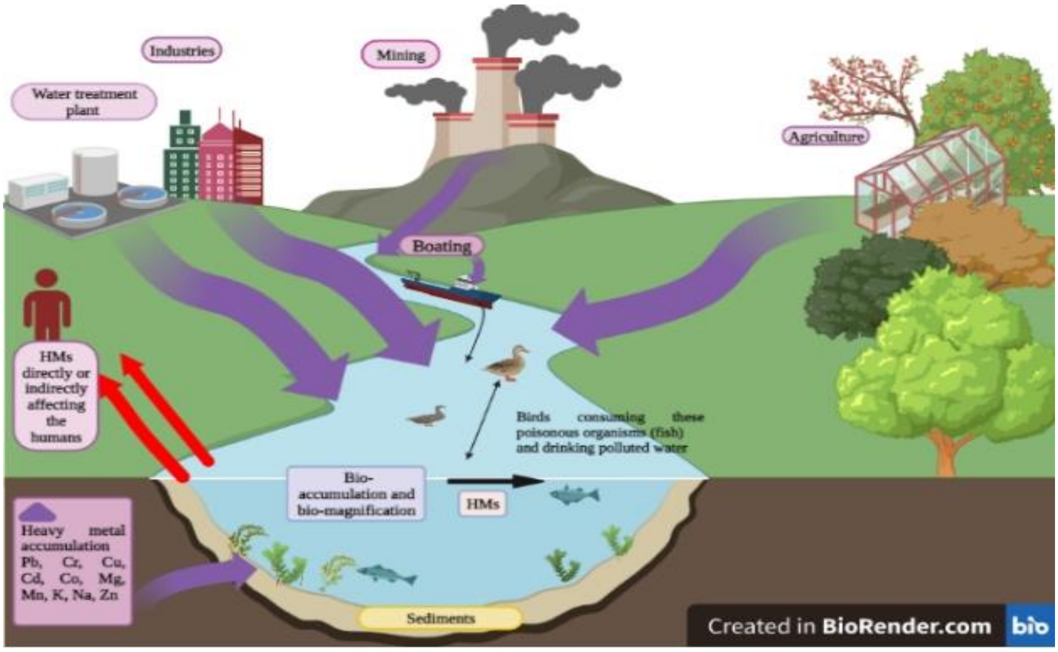


Figure 2: Anthropogenic sources of metals in the environment. (Created with BioRender.com)

4. Heavy metal contamination

Heavy metals in water constitute a global threat to all life forms, hence they must be removed. Heavy metal contamination of biota and groundwater is dangerous to humans. Assessing the level of contamination in riverine ecosystems requires knowledge about heavy metal concentrations and patterns. Physicochemical and meteorological circumstances affect heavy metals' global dynamics and biogeochemical cycles.

4.1. Heavy metals in freshwater ecosystems

As the "lifeblood" of the biosphere, water is crucial to its proper functioning. Many inorganic, organic, and environmental contaminants can be dissolved in water, making it a useful solvent. Concentrations of Heavy Metals in Pakistani Dam Water.

Table 1: The average metal contents (mg/L) in water samples from various dams in Pakistan are shown. Blank cells represented missing data from these sources. CMC = criteria maximum concentration; ND = not detected.

Dams	Cd	Cr	Cu	Pb	Ni	Zn	Fe	Co	Ca	Mg	Mn	Na	K	Li	Ref.
Mangla	0.192	0.067	0.011	0.167	0.111	0.135	0.197	-	-	-	0.062	7.164	-	-	[1]
	0.03	0.08	0.02	0.38	0.13	0.03	0.15	0.25	43	3.4	0.01	2.4	1.3	0.01	[29]
Rawal	0.006	0.009	0.01	0.168	-	0.014	0.093	0.011	12.89	4.9	0.004	13.51	3.14	0.006	[30]
	0.03	1.17	0.08	0.41	0.51	3.45	30.04	0.18	644.74	158.1	0.06	63.24	24.75	1.18	[31]
	0.06	0.26	0.15	0.54	0.26	0.73	1.96								[32]
Shahpur	-	BDL	1.63	8.15	1.19	-	1.52	-	-	-	-	-	-	-	[33]
Zabi	ND	0.05	1.43	1.92	-	2.65	34.71	-	-	-	-	-	-	-	[34]
Changhoz	ND	-	0.02	1.86	ND	0.22	3.04	-	-	-	-	-	-	-	[10]
Dharmalak	0.054	18.16	ND	0.003	ND	0.41	-	-	-	-	-	-	-	-	[35]
Ghol	-	0	0.6968	0	0	1.94	3.81	-	4.80	-	-	-	-	-	[36]
Water quality criteria for drinking water															
WHO (2008)	0.003	0.05	2	0.01	0.07	3	0.3	0.04	100	50	0.1	200	12	0.02	[37]
Pak-EPA (2008)	0.01	0.05	2	0.05	0.02	5	-	-	200	-	0.5	-	-	-	[38]
Standards for the safety of aquatic life in freshwater environments.															
USEPA (2006), CMC	0.005	0.1	1.3	0.015	0.7	5	0.3	-	-	-	0.05	-	-	-	[39]

Heavy metal concentrations such as Na, Cu, Ni, Zn, Fe, Mn, Pb, Cr, and Cd were observed by [1] in Mangla Dam. Sodium was the most abundant element by far (7.164), followed by iron (0.2197), cadmium (0.2192), lead (0.2167), zinc (0.135), nickel (0.0111), chromium (0.062), manganese (0.011), and copper (0.011). In terms of the average metal concentration, the water sample rankings were as follows: Na > Fe > Cd > Pb > Zn > Ni > Cr > Mn > Cu.

The mean and seasonal concentrations of specific metals in water samples from Mangla Dam were observed by [29]. Summer metal concentrations were: Ca > Mg > Na > K > Pb > Co > Sr > Fe > Ni > Cr > Cd > Zn > Cu > Mn > Li. Cd, Co, Cr, Fe, K, Ni, Pb, and Zn averaged higher in summer. Surface water Cd, Co, Cr, Fe, K, Ni, Pb, and Zn concentrations increased in the summer due to heavy precipitation, snow melts, considerable water imports, and expanding anthropogenic activity. The highest Fe and mean Cd, Co, Cr, Ni, and Pb contents exceeded WHO[40], USEPA [39], and Pak EPA [38] limits (Table 1). Cd, Co, and Pb values exceeded water standards by many times.

[30] Observed the mean and seasonal concentrations of specific metals in Rawal Dam's water samples are listed. On average, metal concentrations decreased: Na>Ca>Mg>K>Pb>Fe>Zn>Co>Cu>Cr>Cd=Li>Mn. According to measurements taken in the summer, the most prevalent ions were sodium (13.51) and calcium (12.89) followed by magnesium (4.992), potassium (3.140), and lead (0.162) in that order. The lowest average concentrations were found for Mn, Cd, and Li (0.004-0.006 mg/L). The average levels of Cd and Pb were significantly higher than national and international standards, suggesting that the water may have been polluted as a result of human activity and is therefore unfit for human consumption. The majority of metals are below the acceptable threshold.

[31] Investigated the average and periodic values for specified metals in water samples from Rawal Dam were recorded. However, the following are the average metal concentrations after the monsoons: The order of importance is Ca > Mg > Na > Fe > K > Zn > Cr > Li > Pb > Co > Ni > Cu > Mn > Cd. Ca concentrations ranged from 55.69 to 1652.21 mg/l, making it the most abundant of the major elements in the water after the monsoons. The correlation between calcium and iron suggests they come from the same weathered mineral source.

In Rawal Dam water had an average Cd concentration of 0.06 ± 0.01 mg/L, which is above suitable borders (0.003 and 0.01 mg/L) as discussed by [41]. Cu concentrations at selected areas ranged from 0.11 to 0.19 mg/L, within the 2.0 mg/L limit. Rawal Dam's surface water had an average Zn concentration of 0.73 0.32 mg/L, well below the maximum permissible concentration of 3.0 mg/L. Ni levels far beyond the permissible threshold (0.02 mg/L). Ni concentrations ranged from 0.23 to 0.28 mg/L in some places, with an average of 0.26 0.02 mg/L. The average Fe concentration in the dam was 1.96 0.31 mg/L, which is too high. The high metal contamination in the catchment area of Rawal Lake is caused by rock weathering, human habitation, and agricultural and recreational activities, as stated by the Pakistan Environmental Protection Agency, Ministry of Environment Islamabad. Metal pollution in Rawal Dam is a direct result of human habitation in the areas around Rawal Lake, including Malpur, Bani Gala, Noorpur Shahan, and Bhara Kahu. The sewage and trash from these communities end up in Rawal Dam, making it unusable. Heavy metal fertilizers such as Cd, Pb, Cr, Zn, Cu, and Ni have been discovered to contaminate agricultural wastewater [43].

The most prevalent heavy metals in the water of the Zabi dam were found to be Fe> Zn> Pb> Cu> Cr> Cd> Ni, followed by the other trace elements. Ni and Cd were not detected in water samples, however, Fe was found to be the most prevalent metal [34]. These values exceed the permitted limit [42]. This could be because of the enormous volumes of sewage from farms and factories that are dumped into the dams. The high value of metals in water can be linked to agricultural and industrial waste material discharge [43]. Combustion of petrol and other fuels in cars may account for the increased amounts of lead seen in water samples of the dam [44]. Zinc leached from boat defense plates containing active zinc may explain Dam's highest Zn content [45].

The following heavy metal concentrations were observed by [5] in Shahpur Dam water: Pb > Ni > Fe > Cu > Cr, with Pb, Ni, and Fe all above WHO safe drinking water recommendations (UNEPGEMS 2006). Only Pb and Fe were traceable in the standard reference water, even though Ni, Cu, and Cr were discovered at lower concentrations. Dam water can contain a lot of lead because it's close to a lot of commercial and residential locations. A stone crusher, a glass factory, a ghee plant, a marble factory, two farms with chickens, two mills, and an oil processing facility are among these establishments. This water is neither fit for human consumption nor for maintaining aquatic biota due to the increased levels of Pb and Ni.

Table 1 displays the measured water values near Changhoz Dam's discharge, where Fe> Zn> Pb> Cu> Cr> Cd concentrations are at their greatest levels and chromium and nickel are completely undetectable [34].

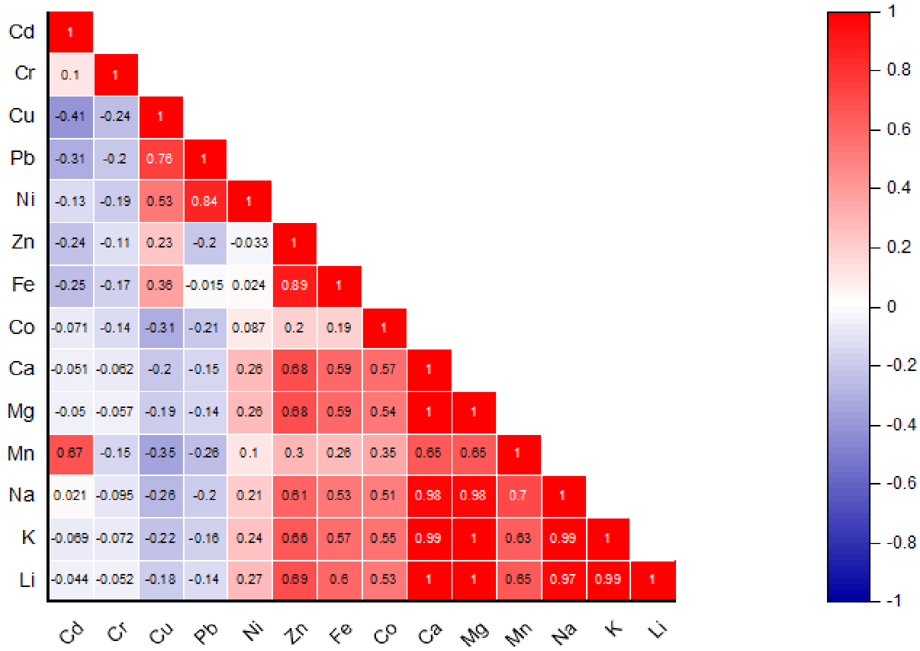
Ni and Cu were not discovered in the Dharmalak Dam water [46]. But quantifiable substances included Cr (18.16 ±4.087), Cd (0.054 ± 0.043), Zn (0.418 ±0.021), and Pb (0.003 ±0.171).

The reported concentration gradient for heavy metals in the Ghol Dam's water is Ca > Fe > Zn > Cu > Ni > Pb = Cr as discussed by [36]. Water samples from the Ghol dam contained substantial concentrations of heavy metals (Ca, Fe, Zn, and Cu), but not of Ni, Pb, or Cr. In comparison to the permitted maximum, these concentrations were extremely high [42]. There could be a link between this and the enormous amounts of sewage from industry and farms that are discharged into the reservoirs. The disposal of industrial and agricultural waste has led to a significant concentration of metals in the water supply [45]. All of the dams' water samples had greater lead (Pb) concentrations, which may be linked to the combustion of gasoline and other fossil fuels [44]. The water from Ghol Dam has the highest quantities of Zn worldwide [45]. This could be a result of zinc being leached from boat armor plates that contain active zinc material.

When comparing the average metal concentration across all dams, the order of Rawal > Zabi > Dharmalak > Shahpur > Mangla > Ghol > Changhoz was observed. The average concentrations of metals in these dams monitored the pattern Ca > Mg > Na > K > Fe > Cr > Pb > Zn > Cu > Li > Ni > Co > Cd > Mn.

Concentrations of heavy metals in the water of various Pakistani dams are shown to have a positive Pearson correlation in Graph 1. Because of the positive correlation ($r > 0$), we can infer that there is a common source of contamination for the metals and that

their concentrations tend to rise as those of other metals rise. In general, the concentrations of two metals will vary inversely across sample origins if there is a negative correlation between them (r < 0). This could point to the presence of factors that affect metal distribution in distinct ways, such as distinct metal sources or contamination pathways.



Graph 1: Pearson correlation between heavy metals from different Dams in Pakistan. Most of the metals have positive correlations such as Ca, M,g, and Na with Li and K indicating their common source of contamination. Cd is positively correlated with Mn, and Cu is correlated with Fe, Z, Ni, and Pb. The blue area is showing the metals having a negative correlation with other metals such as Cr, Cu, and Pb. The scale is showing the values of the correlation coefficient.

4.2. Heavy metals in Sediments and Soil:

Sediment contamination by heavy metals poses a serious environmental threat to marine life. In the aquatic environment, sediments serve as the primary repository for metals. Their caliber may indicate water contamination levels well [47]. Sediments release heavy metals into the water column, acting as both a source and sink for them [48]. Persistent heavy metal deposition in sediments can pollute groundwater [51]. Increased concentrations of toxic heavy metals in river sediments could threaten the ecological stability of benthos (bottom-dwelling species) [52]. Sediment heavy metal concentrations from several Pakistani dams are shown in Table 2.

Dams	Cd	Cr	Cu	Pb	Ni	Zn	Fe	Ca	Co	Mn	Na	K	Mg	Li	Ref.
Mangla	0.281	1.099	0.467	0.81	0.663	0.793	72.70	-	-	7.451	11.748	-	-	-	[1]
Rawal	0.043	0.309	0.161	0.869	-	0.360	21.5	15.5	0.189	0.386	37.37	21.7	6.5	0.395	[49]
Zabi	ND	0.05	4.67	2.98	0.41	3.14	39.96	-	-	-	-	-	-	-	[34]
Dharmalak	0.122	33.07	ND	1.551	0.226	1.522	-	-	-	-	-	-	-	-	[35]
Ghol	-	0	1.001	0	0.003	1.001	6.014	4.081	-	-	-	-	-	-	[36]
Permissible limit by WHO/ USEPA	0.003	0.02	1	0.2	0.01	0.05	1	0.8	-	0.4					[40]

Table 2: MeanTable 2: Metal concentrations (mg/L) in sediments taken from several Pakistan dams. Blank cells show no reported values of these metals in these publications. ND=not detected

Mangla Dam had an average concentration of 72.706 parts per million of iron and average values of 11.748, 7.451, 1.099, 0.793, 0.663, 0.467, and 0.181 parts per million of sodium, manganese, chromium, zinc, nickel, copper, cadmium, and lead. The average quantities of the following were found in sediment samples: Metals in order of increasing toxicity: Fe > Na > Mn > Cr > Zn > Ni > Cu > Cd > Pb [1].

Mean values of 37.37, 21.70, 21.54, and 15.51 mg/kg for Na, K, Fe, and Ca are presented in Table 2 for the water extract of the soils at Rawal Dam, indicating that these are some of the principal elements present. The next most abundant elements are magnesium (6.468 mg/kg) and lead (0.869 mg/kg). The average concentrations of Li, Mn, Zn, and Cr are predicted to be almost identical, whereas those of Co, Cu, and Cd are predicted to be the lowest. Elements are given in descending order of average concentrations in sediments collected from water: In descending order of toxicity, we have Na > K > Fe > Ca > Mg > Pb > Li > Mn > Zn > Cr > Co > Cu > Cd [50].

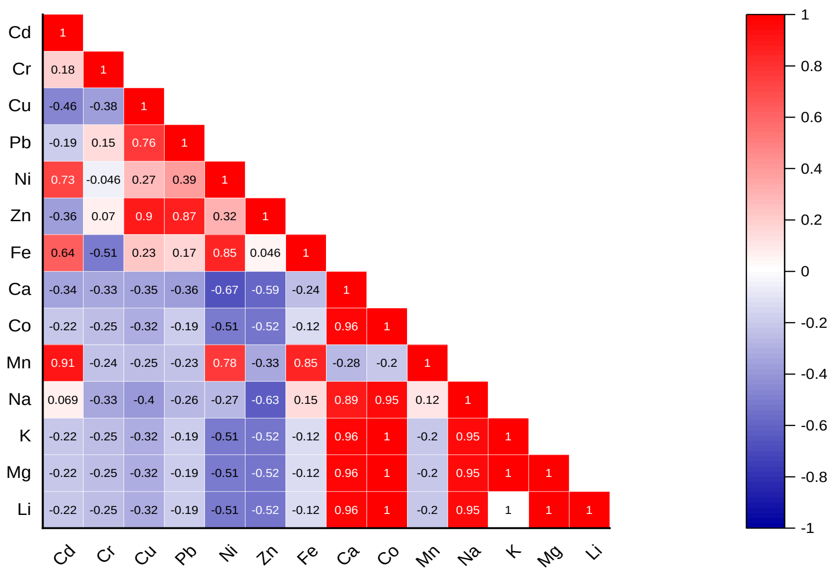
In Zabi Dam, heavy metal concentration in soil was discovered in the subsequent direction: Fe> Cu> Zn> Pb> Ni> Cr> Cd [34].

The heavy metals in the soil of Dharmalak Dam were in the direction Cr>Pb> Zn> Ni> Cd. Cr was the most abundant metal in soil, with a concentration of 33.07 11.37 μg/g. Pb, Zn, Ni, and Cd were next, with concentrations of 1.551 0.249, 1.522 0.026, 0.226 0.006, and 0.122 0.011, respectively [46].

Soil heavy metal content of Ghol Dam was Fe>Ca>Cu=Zn>Pb>Ni=Cr. The Ghol Dam soil samples had the highest levels of metals (Fe, Ca, Cu, and Pb) but no Ni or Cr [36]. Iron toxicity harms plants, animals, and humans [25]. Lead causes anemia, brain damage, and vomiting [27]. Leaded petrol, other petrol, and agricultural and industrial wastes may contribute to soil lead levels [28]. Comparing soil and water heavy metal accumulation.

Because all dead organic stuff is kept in the ground, damaging the environment, the soil has more metals than water.

The general pattern of mean metal concentration in all dam sediments was Rawal > Mangla > Zabi > Dharmalak > Ghol. Sediments from these dams often have higher quantities of Fe than Na, Cr, K, Ca, Mn, Zn, Mg, Cu, Pb, Ni, Cd, Li, and Co on average.



Graph 2: Pearson correlation between heavy metals in sediments from different Dams of Pakistan. Ca, Co, and Na have positive correlations such as with Li, Mg, K, and Na indicating their common source of contamination. Cd is positively correlated with Mn, Fe, and Ni, and Cu is correlated with Zn and Pb. The blue area is showing the metals having a negative correlation with other metals such as Cr, Zn, and Pb. The scale is showing the values of the correlation coefficient.

4.3. Heavy metals in Fish

Exposure to heavy metals affects fish in several ways, altering their physiology and chemistry. Metal accumulation in organs can cause morphological and functional problems in fish. It comes as no surprise that consuming contaminated fish can place others at risk of ingesting dangerous levels of certain heavy metals (Cong, Pang, et al. 2022), [51]. Fish with increased metal levels are used as bio indicators of metal contamination in water systems. Fish play a significant role in the food web because they act as a route for heavy metals up the food chain [52, 53]. It is well recognized that metals accumulate in fish populations and pose health risks to humans. Scientists have been monitoring the effects of metal exterminating on different fish species for quite some time. Extensive studies have connected heavy metal consumption to a wide range of negative health consequences, such as kidney damage (Pb, Cd, and Hg), cognitive impairment (Pb and Hg), reproductive problems (Cd and Pb), and abnormalities in the brain (Hg and Pb), mutagenic disorders (Hg), and cancer (Cd) [54].

Dams	Fish	Organs	Cu	Pb	Fe	Ni	Cd	Zn	Cr	Co	Mn	Na	Ca	K	Mg	Li	Ref.
Mangla	*C. carpio*	Muscles	1.37	6.05	16.9	2.37	0.52	161	0.61	2.90	2.29	648	435	3002	227	0.09	[55]
		Gills	4.52	12.5	772	9.95	1.65	2807	3.75	19	24.7	1755	7885	2233	1323	0.87	
		Scales	2.44	8.25	24.6	4.85	0.82	434	2. 83	13.5	11.8	442	4357	359	529	0.72	
Rawal	*N. tilapia*		0.04	0.08	0.07	0.34	1.51	1.22	0.01	-	-	-	-	-	-	-	[32]
Shahpur	*C. carpio*	Gills	35.5	13.9	106.5	BDL	-	-	1.6	-	-	-	-	-	-	-	[33]
		Muscle	13.6	21.7	58.2	0.2	-	-	BDL	-	-	-	-	-	-	-	
		Liver	120.7	8.9	162.7	BDL	-	-	1.13	-	-	-	-	-	-	-	
		Kidney	18.7	18.3	66.8	BDL	-	-	0.2	-	-	-	-	-	-	-	
		Brain	20.6	9.3	42.1	BDL	-	-	0.08	-	-	-	-	-	-	-	
Changhoz	*H. nobilis*	Head	0.059	4.801	3.027	ND	ND	1.184	-	-	-	-	-	-	-	-	[10]
		Abdomen	0.085	4.104	2.642	ND	ND	0.579	-	-	-	-	-	-	-	-	
		Tail	0.089	3.215	3.098	ND	ND	1.328	-	-	-	-	-	-	-	-	
		Scales	0.077	3.089	25.84	ND	ND	2.150	-	-	-	-	-	-	-	-	
	H. molitri	Head	0.023	4.924	5.417	ND	ND	1.565	-	-	-	-	-	-	-	-	
		Abdomen	ND	3.651	6.604	12.47	ND	0.648	-	-	-	-	-	-	-	-	
		Tail	0.120	2.668	9.396	ND	ND	2.213	-	-	-	-	-	-	-	-	
		Scales	0.105	3.105	3.938	ND	ND	2.512	-	-	-	-	-	-	-	-	
	C. latius	Head	0.192	3.529	2.791	2.336	ND	2.638	-	-	-	-	-	-	-	-	
		Abdomen	ND	2.933	4.050	2.234	ND	2.242	-	-	-	-	-	-	-	-	
		Tail	0.088	2.624	3.416	ND	ND	2.158	-	-	-	-	-	-	-	-	
		Scales	0.116	5.014	1.666	0.186	ND	2.243	-	-	-	-	-	-	-	-	
WHO (1989)			30	0.2	100	0.50 - 0.60			-								[5]

Table 3: Mean metal concentrations (mg/L) in different organs of various fish species taken from several Pakistan dams. Blank cells show no reported values of these metals in these publications. ND=not detected. BDL=Beyond the detection limit.

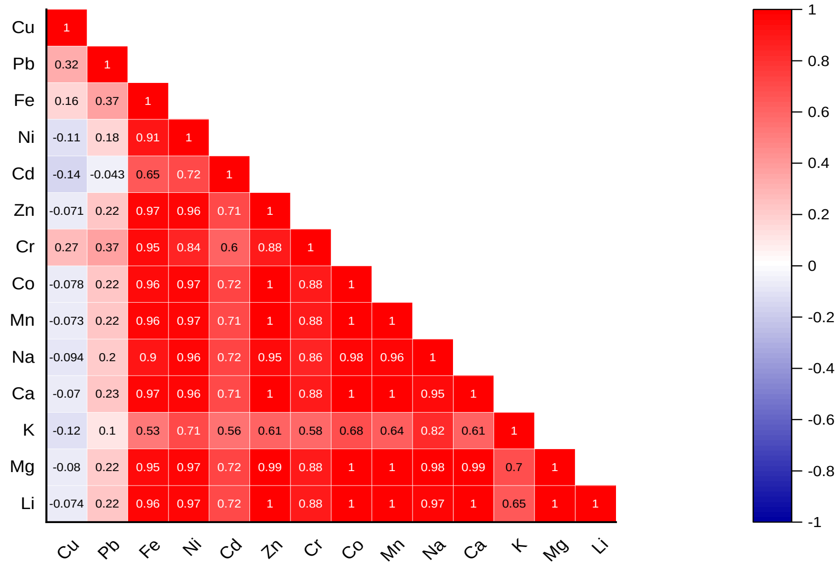
Mangla Dam *Cyprinus carpio* muscles have been measured in ppm for the concentrations of specific toxic and vital elements. The muscle of *Cyprinus carpio* displays the following declination: Na, Ca, Mg, Zn, Fe, Pb, Sr, Se, Co, Ni, Mn, As, Cu, Cr, Cd, Hg, and Li come after K. The following decreasing order can be observed in the typical concentrations of the gills: Zn, K, Na, Mg, Fe, Sr, Mn, Co, Pb, Ni, Cu, Cr, Se, Cd, Li, As, and Hg succeed Ca. The average metal content of the scales exhibited the following downward trend: The elements following Ca are Mg, Na, Zn, K, Sr, Fe, Co, Mn, Pb, Ni, Cr, Se, Cu, Cd, Li, As, and Hg [59]. The results demonstrated that metals accumulate in specific body regions: Cd, Pb, Ni, Cr, Co, Cu, Fe, Li, Sr, Ca, Mg, Mn, and Zn had higher levels of metals in gills and decreased in tissue order: gills > scales > muscles, whereas As, K, Hg, and Se had muscles > gills > scales. Na mostly helped with the gills and only a little with the scales. Since gills are more exposed than muscles, their metal levels are higher. Due to the persistence of the metal-mucus complex on the lamellae, gills, a dynamic metabolic tissue, tend to collect higher metal concentrations than muscles. [56]. Due to their enormous surface surfaces, gills rapidly diffuse harmful metals from water. Thus, water is thought to cause gill metal buildup [57].

Table 3 displays the metal content in the musculature of *Nile tilapia* captured in Rawal Dam. All fish samples contained elevated levels of Pb, Cr, Cd, Cu, Zn, and Ni; their average concentrations were 0.08, 0.01, 1.51, 0.04, 1.22, and 0.34 mg/L, correspondingly. Each of these outcomes exceeded the WHO's established guideline benchmark. Metals in Rawal Dam's surface water accumulated in this sequence: Fe > Zn > Pb > Cr > Ni > Cu > Cd, however in the muscles of Nile tilapia, the order was Cd > Zn > Ni > Pb > Fe > Cu > Cr. By the discussion in [62], bio magnification causes the average concentration of Cd and Zn in fish muscles to be higher than the average concentration of these metals in water, while the average level of Pb, Fe, Cr, and Cu is lower, indicating that fish muscles are not accumulating these metallic substances in high amounts due to their less age, terms of size, and mass. Toxicity accumulation increased with age, weight, and size, according to [58] and[58]. According to [59] fish muscle is an important issue for metals toxicity monitoring because humans eat it.

All organs of exposed fish contained between 21.7 and 8.9 mg kg1 DW of lead. There was a wide variation in Cu and Cr concentrations from 120.7 to 13.6 and 1.6 to 0.2 mg kg1 DW in the gills and liver, respectively. Iron concentrations ranged from 162.7 to 42.1 mg kg1 dry weight and were marginally higher in fish liver, whereas Ni concentrations were below the limit of detection in virtually all organs. The accumulation order of metals in exposed fish was Pb > Cr > Cu > Fe > Ni. Most metals, including Pb, were detected at higher concentrations in the gills and liver, as metals tend to accumulate in organs with direct exposure or metabolically active tissues. Effluents from nearby companies and farms caused metals to bioaccumulation in dam water and biota. During respiration, the gill collects metals. The liver stores and detoxifies food-borne heavy metals. Thus, it stores toxins before delivering nutrients to the body. Agriculture, poultry farms, industry, and other activities may increase fish Pb levels [60]. Natural protein binding like metallothioneins is linked to liver metal overload[61]. *Cyprinus carpio's* high metal bioavailability generated massive Pb, Cu, and Cr bioaccumulation in the liver and gill [5].

In Changhoz Dam, the amounts of metals in the musculature of three chosen species were determined to be as follows: K>Na>Ca>Fe>Cr>Mn. In this study, *Hypophthalmichthys nobilis* has the greatest iron Fe in scales, Pb in the head, zinc in scales, and copper in the tail, but no cadmium or nickel. Copper, iron, nickel, zinc, and lead were found in *Hypophthalmichthys molitrix*, but cadmium was absent. *Crossocheilus latius* has the highest quantity of copper in the head, iron in the abdomen, nickel in the head, zinc in the head, lead in the scales, and no cadmium[10].

In comparison to other dams, Mangla Dam generally has a higher mean metal concentration in its fish. Out of the three species found at Changhoz Dam, *H. molitri* has the highest metal concentration, followed by *H. nobilis* and *C. latius*. The dams with the highest metal concentration in fish were Mangla, followed by Shahpur, Changhoz, and finally Rawal.



Graph 3: Pearson correlation between heavy metals of sediments from different Dams of Pakistan. Almost all metals are strongly correlated with each other indicating the influence of these metals on each other. The heavy metals are accumulated from water in the organs of fish. Ca has a strong positive correlation with the other metals. The scale is showing the values of the correlation coefficient.

4.4. Heavy metals in Birds

Birds are vulnerable to heavy metals due to their exposure in three main ways: food, water, and geophagy (eating soil-like particles to absorb minerals like sulfur and phosphorus). Heavy metals have varying assimilation rates due to their distinct chemical and physical properties, the physiological requirements of various species, and the media in which they are found. Ingested metals travel throughout the body, deposit in organs, are ejected immediately, or are retained in the animal's feathers [62].

Heavy metal pollution can be measured non-destructively with feathers. Bird feathers could be used in environmental research as a non-invasive bio-monitoring tool. Hairs [63] and feathers [64] have been used in non-destructive heavy metal and organic pollution monitoring studies [65-67]. Heavy metal contamination in birds has also been evaluated and monitored across Pakistan's several ecological regions [68, 69]. [68] Heavy metal and other remnants were discovered in the plumage of the Laggar falcon, and Falco *biarmicus jugger,* from six Pakistani regions. The presence of heavy metals in mature and young plumage indicated contamination levels. Using the eggs and feathers of migratory waterfowl such as the little, intermediate, and cattle egrets.[70] Monitored heavy metals poisoning in three Pakistani wetlands. The published literature contains scant information regarding the prevalence of heavy metals in migratory birds that land at Pakistan's freshwater reservoirs. There is scant information in the published literature about the presence of heavy metals in the birds of passage that land at Pakistan's freshwater reservoirs. A better framework is required for future studies of heavy metal detection in migratory birds.

Dams	Birds	Cd	Cr	Cu	Pb	Ni	Zn	Fe	Co	Ca	Mg	Mn	Na	K	Li	Ref.
Rawal	*Bublus ibis*	2.7 ± 0.7	5.38 ± 1.0	4.0 ± 1.3	60.2 ± 20.7	7.8 ± 11.8	138.4 ± 49.2	117.7 ± 29.4	6.1 ± 2.2	20,398.1 ± 4,019.8	1,272.9 ± 246.5	16.9 ± 7.1		2,391.2 ± 41.7	0.8 ± 0.3	**[71]**

Table 4: Mean metal concentrations (ppm) in feathers of Bublus ibis taken from Rawal dams

Overall, the feathers tested positive for elevated levels of the main metals Ca, Mg, and K, all indicative of a natural origin (Table 4). The trend of Calcium > Potassium > Magnesium > Zinc > Iron > lead> manganese> nickel> cobalt> Cadmium >Copper > Sodium > lithium shows the distribution of these metals in the Rawal Dam [72].

Pb, Mn, Fe, and Ca contents may vary due to local contamination and pollution sources and metal deposition in cattle egrets' feeding. Heavy metals can get on feathers from the outside in one of two ways: either the feathers are contaminated by heavy metals in the environment, which is usually caused by humans, or the bird's uropygial gland excretes heavy metals onto the feathers when it preens [73]. One possible explanation for the high concentrations of lead found in feathers is the continued use of leaded fuel in Pakistan. More information is needed about Pb emissions in Pakistan's cities [72].

5. Heavy metal trophic transfer

Metal pollution of agricultural land is a rising problem around the world, especially in Pakistan [74]. The bioavailability and harmfulness of heavy metals vary with the kind of speciation they take. Due to their mobility and bioavailability, soluble metal species pose the greatest risk to human health [75]. Fish consumption raises public health concerns regarding the bioaccumulation of harmful heavy metals [76]. Harmful effects on human health have been linked to exposure to heavy metals in fish at unsafe levels [77]. Consuming wild fish frequently from water sources affected by industry may provide health risks [78].

It is crucial to investigate how harmful heavy metals travel up food webs and chains. The contaminants reach the food web when biota absorb heavy metals from the environment that is abiotic (water, sediments, soils). As heavy metals accumulate in food chains, they can have a "biomagnifying" effect. Heavy metals and metalloids, which pose a threat to both human and animal well-being, are ingested and then move up food chains via trophic transfer, bioaccumulation, and biomagnification. Humans can absorb heavy metals through their skin, lungs, and digestive systems. Diseases and health issues such as neuropathy, nephropathy, osteoporosis, osteomalacia, endocrine disruption, cancer, tumors, mutations, physical birth deformities, etc. are all caused by disruptions in normal body function.

6. Conclusion

As a consequence of industrialization and urbanization, human-caused sources and inputs of heavy metals have increased in the environment. Due to their toxicity, persistence, and bioaccumulation, heavy metals are generally regarded as environmental hazards. Rawal Dam has a significant concentration of heavy metals because of the large number of uncontrolled discharges of industry and wastewater from metropolitan areas and industrial fields. Therefore, the ecological status of both of these rivers is deteriorating. Some areas of Changhoz Dam are moderately contaminated with metals. Bioaccumulation and even biomagnification of certain elements in food chains originate from their transfer from the abiotic environment to living species. These elements bioaccumulate in biota, contaminating food webs as a result. Heavy metal enrichment in biota is harmful to the species exposed to it and to those who eat those organisms. As a result, the heavy metals' potential to bioaccumulate and biomagnify poses serious risks to both animal and human health.

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