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# Accumulation of Heavy Metals in Sewage Fed Aquaculture of India : A Review

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## ABSTRACT

Sewage fed aquaculture is a novel approach to efficiently convert waste material into fish production. The source of sewage in cities includes a large portion of industrial effluents. Often, the drainages from the industries contain several toxic chemicals including heavy metals like cadmium, arsenic, lead, mercury, nickel, copper. These metals eventually come to the sewage fed pond if the wastewater is not treated properly. The metals contaminate the water and the sediments. Afterward, they are ingested by the fish and other aquatic organisms and accumulate in them. The concentrations of the metals are generally high in liver, kidney and other internal organs compared to muscles. These contaminated fishes are consumed by the human and can result in toxic effects. Regular intake of heavy metals with food can cause neurological symptoms, skin problem, damage of internal organs, cancer and even death. Discarding the offal portion during fish preparation and treating the sewage water before using it in aquaculture can save us from the threats of heavy metals.


**Keywords** Sewage fed aquaculture, Heavy metals, Fish.

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## INTRODUCTION

Culture of fish in sewage water is not a new practice, especially in India. A million liters of sewage are produced every day in our country. Majorly, they are disposed of in rivers or oceans and create heavy pollution. In very few cases these are properly treated before releasing to the environment. Alternatively, the use of sewage water for aquaculture is considered as a better solution. Generally, the wastewater contains a good amount of organic matters and can efficiently be used as feed for the fishes. Sewage fed aquaculture has become a very common and economical practice in different places in India. But, this system can cause a severe threat to human being. It is well known that the wastewater includes drainages from industries, agriculture and households. Often, it is contaminated with numerous toxic chemicals including heavy metals (Adhikary et al. 2019). The concentration of these elements crosses the safe level and causes environmental pollution. Eventually, they are consumed by the fishes cultured in the sewage fed aquaculture. Heavy metals like arsenic, cadmium, lead, mercury, copper are very much stable, persistent and non-degradable in nature. They accumulate in different tissue of the fish. When these fishes are consumed by a human being, a serious health risk can arise. So, it is utmost important to know about the consequences of heavy metal pollution in sewage fed aquaculture. In this review, we have briefly described how the metals pollute the water, accumulate in fish tissue and results in a human health hazard.

**Sources of heavy metals in sewage**

There are two major sources of heavy metals in sewage water i.e. natural and anthropogenic (Akpor et al. 2014). The natural sources include soil erosion, volcanic eruption. It contributes very less compared to human factors. Anthropogenic causes mainly comprise of textile industries, thermal power plants, mining operations. Among the natural sources,volcanic eruptions result in the emission of several pollutants containing heavy metals. Metals like lead, arsenic, copper, zinc are often present in the volcanic ashes (Dongarrà and Varrica 1998). They contaminate the soil, water and other natural resources near the volcano. Another natural source includes soil erosion (Akpor et al. 2014). It can be causd by heavy rainfall or wind flow. Many metals present in the soil leaches away with water during rain. It is finally drained to the nearby water bodies including a pond, river. The major portion of heavy metals present in the sewage is contributed by human activities. With the rapid increase in human population in India, environmental pollution has also increased. During the course of modernization and industrialization, we have abruptly destroyed the natural resources.The number of cities has increased and simultaneously the amount of waste also. It has resulted in an increased amount of Municipal wastes in urban areas. In metro cities like Kolkata nearly 545 million liters per day (MLD) of domestic wastewaters, 227 MLD of industrial wastewater and stormwater (during monsoons) are carried out by the main pumping stations and intermediate smaller pumping stations (Adhikari et al. 2009). Lokhande and coworkers (2011) during conducting a study in Tajola industrial area of Mumbai; found that the industries present their use about 45,000m$^3$/day of freshwater and discharge about 28,750 m$^3$/day effluent/day. A number of heavy metals are present at high concentration in industrial sewage. It has been found that electroplating, electrolysis deposition, anodizing cleaning and related industries are a good source of several metals like cadmium, lead, nickel, vanadium, silver, titanium. Lead and tin are also found in sewage from the printed circuit board manufacturing industries. Petroleum refining also contributes in nickel, vanadium and chromium pollution (Gunatilake 2015). There are several methods which can be applied to purify the industrial effluent before releasing it to the environment. But, unfortunately, these are not followed all the time. In cities, the wastewater is discharged from the terminal pumping stations to the wetlands through several flow channels (Adhikari et al. 2009). Some water is also carried to the river through drains. This wastewater is extensively used for sewage fed aquaculture. So, all the heavy metals come to the ponds and other water bodies and contaminate it. Consequently, the level of pollution in surface water increases up to 20-22 times above the safe level (Lokhande et al. 2011). Almost all the rivers, ponds and other water bodies are polluted now. This creates a severe problem in aquatic life and health hazard in human being.

**Heavy metals in water and sediment**

After release into the environment, heavy metals can be detected in both water and sediment of the ponds. Several studies have been carried out throughout India to determine the level of metals in sewage water. In a study conducted by Maiti and Banerjee (2012), it was found that sewage fed aquaculture in East Kolkata Wetlands contains a high level of heavy metals. The level of Cu, Pb, Zn and Cd in sewage water was 10.97 ± 2.87, 93.33 ± 9.39, 16.44 ± 5.59 and 2.23 ± 0.74 µg/g respectively and in sediment was 41.00 ± 5.00, 32.00 ± 2.18, 60.80 ± 9.11, 3.48 ± 1.11 µg/g respectively. Chattopadhyay et al. (2002) conducted a similar study in Kolkata and found that concentration of Cr, Zn, Cu, Pb, Mn, Fe and Mg in the raw sewage water ranged 0.05–0.2, 0.18–0.30, 0.20–0.29, 0.39–0.72, 0.9–1.40, 2.92–4.30 and 104.95–110.31

mg/l respectively. It was also reported by them that the nearby industries such as tannery, rubber factory, electroplatin, pigment manufacturing unit, potteries, battery manufacturing plants ar mainly responsible for this contamination. Effluent from them directly mixed with the city sewage. In a study conducted by Lokhande and coworkers (2011) in Mumbai, it was found that dyes, paints, pharmaceutical and textile industries are some of the major industries that are mainly responsible for heavy metal toxicity in the surrounding water bodies. They also reported that paint industries are one of the major contributors of Cr, Zn and Pb toxicity with an amount of 35.2, 33.1 and 31.4 mg/l respectively. Cu was mainly detected in dye manufacturing units with a level of 33.3 mg/l. Textile industries act as a good source of contamination (12.8 mg/l). It was also observed that pharmaceutical industries are a major contributor of Cd and Ni amounting to 35.8 and 33.6 mg/L respectively. In the majority of the cases, the water was released without treatment and used directly for agriculture and aquaculture. In the study conducted by Adhikari et al. (2009) it was found that the level of Pb, Cd and Zn in water was 22, 32 and 16 μg/l respectively and in sediment was 50.5, 10.1 and 140.6 mg/kg respectively. Cr and Cu were present at 77.4 and 30.1 mg/kg concentration. In all the cases described above, it can be observed that sediments contain more metals compared to wastewater. In the majority of the cases, the level crossed the threshold safety limit. It indicates a potent danger for aquaculture practice in these areas. In the city of Varanasi, Uttar Pradesh, a research was carried out by Mishra and Tripathi (2008). They reported a high concentration of Cd in wastewater than the permissible limits prescribed by the World Health Organization and ensure about the possible health hazard in human. Puttaiah and Kiran (2007) reported that the concentration of Cu ranged from 1.042 to 1.30 mg/l in sewage water, while, that in sediment ranged from 89.75–90.01 mg/kg in sewage fed lake of Karnataka. The WHO guidelines for the maximum permissible limit of copper are 0.05 mg/l. The range obtained was quite high than the WHO value ; hence, adverse effects from domestic use are expected. Levels of Zn in that lake water and sediment were between 0.35 and 0.92 mg/l and 0.034 and 0.038 mg/kg respectively. The WHO permissible limit is 0.10 mg/l. They also found that the levels of Pb in the water varied between 1.3 mg/l to 2.8 mg/l and between 1.45 mg/l to 2.93 mg/kg in sediment. The concentration of Pb obtained in sediment were higher than those in the lake water, hence the sediment could be an important factor on the level of Pb in lake water with other enhancing factors such as water current and pH. Since acidic water is known to influence the solubility and availability of metals. The WHO (2011) permissible limit for Pb in water is 0.05 mg/l and the mean concentration of Cd in water ranged from 0.06 to 0.094 mg/l while that of sediment varied between 19.0 and 24.0 mg/kg. The range obtained from the lake water was higher than the tentative WHO guidelines of 0.005 mg/l for consumption and domestic use. The concentrations (μg/ml) of heavy metals in the irrigation water at Wastewater (WW) site ranged between 0.00–0.02 for Cd, 0.02–0.07 for Cu, 0.07–0.13 for Pb, 0.05–0.18 for Zn, 0.02-0.08 for Ni and 0.03–0.08 for Cr during March 2006 to February 2007, whereas at Clean water (CW) site , heavy metal concentrations in irrigation water were very low or below the detectable limits. Among all the heavy metals, Cd concentration exceeded the permissible limit set by FAO (1985) (Reviewed in Singh et al. 2010). All these heavy metals in the sewage water were associated with small scale industries such as coloring, electroplating, metal surface treatments, fabric printing, battery and paints, releasing Cd,Cu, Pb, Zn, Ni and other heavy metals into water channels, which are accessed for irrigation. Till date, many fish farmers are cultivating in this water and unknowingly increasing the human health risk. The fish cultivated in sewage water are transported to different markets of our country and affecting our health.

**Accumulation of heavy metals in fish**

It is very clear from the above discussion that a high level of heavy metal is present in the water and sediment of sewage fed aquaculture. These metals are ingested by the fishes and other aquatic organisms. As a result, the metals go to the circulation and accumulate in different tissues of the fish. This accumulation of metals in fish is time-dependent but their distribution depends on the metabolic demand of the various tissues. Besides, environmental factors and other organism factors like feeding habit, habitat, age, sex and bodyweight of fish play a vital role in accumulation (Authman 2008). Thus, the accumulation in various tissues is determined by the relative rates of metal binding and release. Moreover, chronic sub-lethal exposure of one metal can alter the uptake and distribution of another. Besides, accumulated elements are continuously released from the body, which is part of the homeostatic regulation of the organism. Excretion of metals also depends on both environmental and biological factors of a particular species while the final metal concentration in the body is influenced by the organism's ability to regulate these toxic, lipophilic elements.

A number of researches have been carried out in India regarding the accumulation of metals in fish tissue. Many of the times the results are quite threatening for human safety. A study was conducted by Adhikari et al. (2009) in sewage fed ponds of Kolkata. They determined the level of lead, cadmium, chromium, copper and zinc in various organs of *Labeo rohita, Catla catla, Cirrhinus mrigala, Oreochromis mossambicus* and *Cyprinus carpio* cultured in sewage-fed ponds. A significant difference was observed among different metals accumulation in different tissues. The least bioaccumulation was showed by cadmium, while zinc showed the highest accumulation in all the fish species. Among the fish tissues, maximum metal concentration was in kidney and lowest in muscle. The level of metals in muscle was below the prescribed limit of WHO/FAO and was safe for human consumption. Another study carried out at Bonhooghly and Noapara area of Kolkata also reports about the metal accumulation in fishes (Adhikary et al. 2019). These areas receive a huge quantity of sewage from Baranagar municipality area. The level of Cd and Pd in fish tissue ranged from 0.002–0.013µg/g and 0.23–1.84 µg/g respectively. Like other studies, here also, higher concentration was found in internal organs like liver, kidney and gill compared to muscle. Javed and Usmani (2012) investigated the bioconcentration of heavy metals in *Channa punctatus* at Panethi, Aligarh. The found metal accumulation in order Fe>Mn>Zn>Co>Ni>Cu =Cr. In muscle metals accumulation was Fe>Zn>Mn>Cu>Cr>Ni>Co. Except for Cu and Co, all the metals were mainly accumulated in gills. Cu and Co accumulation were maximum in liver and muscle. Bhattacharyya and coworkers (2010) also reported a higher mercury accumulation in *Tilapia mossambicus, Cirrhinus mrigala* and *Labio rohita* fishes collected from East Calcutta Wetlands and Titagarh Sewage Fed Aquaculture. The level of Hg in collected fish ranged from 0.073 to 0.94 µg/g wet weight. The researchers also indicated the risk of mercury toxicity in regular consumers though no cases were reported from that area. All these researches indicate a high accumulation of heavy metals in fish tissue which can result in a serious threat for the fish eating population of our country.

## Human health hazards

Fish is a common food in India consumed on regular basis. Unfortunately, this nutritious food item can cause severe health issue if contaminated with heavy metals. All the heavy metals have serious effects on our body if consumed excess. The toxic effects of heavy metals in the human body are described in Table 1. It is evident that heavy metals can cause great

**Table 1.** Heavy metals and their toxic effects in human.

| Metal | Toxic effects | References |
|---|---|---|
| Arsenic | Skin lesions, blackfoot diseases, proximal tubule degeneration, peripheral neuropathy, encephalopathy, hepatomegaly, cirrhosis of liver, diabetes, bone marrow depression | Abdul et al. (2015) |
| Cadmium | Skeletal demineralization, itai-itai disease, renal, damage, reduced reproductive capacity, neurodegenerative disorder, cancer | Rahimzadeh et al. (2017) |
| Cobalt | Cardiomyopathy, neurotoxicity, contact dermatitis, psychological problem, cancer | Leyssens et al. (2017) |
| Chromium | Bronchial asthma, lung and nasal ulcers and cancers, skin allergies, reproductive and developmental problems, cancer | Shekhawat et al. (2015) |

**Table 1.** Continued.

| Metal | Toxic effects | References |
|---|---|---|
| Copper | Liver damage, Wilson disease, insomnia | Babel and Kurniawan (2004) |
| Nickel | Skin allergies, lung fibrosis, variable degrees of kidney and cardiovascular system poisoning, stimulation of neoplastic transformation | Denkhaus and Salnikow (2002) |
| Zinc | Depression, lethargy, neurological sign | Babel and Kurniawan (2004) |
| Lead | Encephalopathy, peripheral neuropathy, central nervous disorders, anemia | Mahurpawar (2015) |
| Mercury | Rheumatoid arthritis, disease of the kidney, circulatory system, nervous system, Proteinuria | Babel and Kurniawan (2004), Mahurpawar (2015) |

harm to the human body. It affects all the vital organs and can result in cancer or even death.

## CONCLUSION

Sewage fed aquaculture is a common practice in India and helps the farmers to cultivate fish in an easy way. But, the sewage water has become a good reservoir of toxic heavy metals. Generally, domestic sewage doesn't contain many toxic elements. But, the drainage from industries and agricultural lands contains a good amount of heavy metals, pesticides, herbicides. So, it will be better to treat these effluents properly before releasing into the environment. The sewage fed aquaculture is a novel approach to convert wastewater into wealth. Removing the threats of heavy metals will make it more successful. It has been observed that the metals are touching the threshold level in sewage water as well as sediments. They are also accumulating in different fish tissue and causing toxicity. Interestingly, the concentration of metals in the muscle of fish was lower compared to other tissues and was within a safe limit. So, it is advised to discard the offal portion of the fish before its preparation(Ghosh et al. 2019). It is a traditional practice followed in India and can help the fish consumers to get rid of the metal toxicity. Finally, the Government, industrialists and common people should be aware of the threats of the heavy metal toxicity and should try their level best to reduce the environmental pollution, so that we can offer a better future for the next generation.

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