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A Study on Uptake of Heavy Metals on Aquatic Biota

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ABSTRACT

Test aquatic species were gathered from the Godavari River at Ramgarh, Jharkhand in order to investigate the effects of heavy metal ingestion on aquatic biota. Using aquatic biomass cultures and various heavy metal concentrations for a given time period, the effects of heavy metal uptake on aquatic organisms were investigated in a lab setting. The aquatic biomass was filtered through sterile fine nylon fabric, cleaned twice with distilled water, and dried in an oven at 105 degrees Celsius prior to the experiment to determine the initial concentration of heavy metals present in the biomass. Using a pestle and mortar, the dry sample was ground into a fine powder. To estimate Zn, Fe, Cu, and Cd, a weighted quantity of powder was utilized. The study of poisons as a basic science is known as toxicology. Any chemical substance that, when ingested by an animal in minute quantities, malfunctions and compromises its health is considered a poison or toxicant. A natural product of plant or animal origin, or a synthetic substance, can both be poison. Endogenous poisons or toxins are those produced by an organism itself, while exogenous poisons or toxins are those that enter an organism from the outside (the environment). Xenobiotics are the name for compounds that are exogenous.

Key Words: Heavy Metals, Aquatic Biota, Industrialization, Hazardous.

INTRODUCTION

Industrialization, or the establishment of plants and factories, has become a critical aspect in a country's economic development. The trash and by-products emitted by industries and manufacturers appear to be hazardous to the environment. Because those items contain a variety of contaminants, surface and ground waters, as well as soil, are contaminated. A variety of facts support the mistreatment of garbage. The lack of extremely efficient waste treatment technology is one of the primary facts or explanations. The only topic of this chapter is a detailed demonstration of the effects of industrial discharge on environmental health. Industrial enterprises discharge a variety of pollutants into rivers, lakes, and groundwater. Fresh water is unavoidable due to human consumption of it for drinking, bathing, irrigation, and other purposes. The presence of industrial toxins in water can reduce crop yield and plant growth, as well as harm aquatic living species.

India's inland fishing resources are studied for their diversity in composition as well as their potential for production. India has a wide expanse of open inland waters in the shape of rivers, canals, estuaries, lagoons, reservoirs, lakes, ponds, tanks, and so on. The resources are vital sources of income for the rural communities, particularly the fisherman. Approximately 14 million people are currently engaged in fishing, aquaculture, and related industries (Fisheries Division, ICAR, 2006). The most natural system on the world is inland aquatic life. The quality and quantity of water, as well as the timings of its usage, represent the majority of natural and human activity in the basin. Any type of health risk manifests itself as an unfavorable habitat situation. Fish production is highly influenced by ecosystem and health management in inland open waters, which also helps to ensure a sustainable fish catch. With both fatal and non-lethal impacts on living things, heavy metals are regarded as significant hazardous contaminants. Aquatic biota are vulnerable to the negative impacts of metals because they are easily dissolved and transferred in water. Heavy metals have drawn a lot of attention in aquatic environments because of their toxicity and biota buildup (Mason, 1991). Metals' harmful impacts on aquatic ecosystems ranged from a total loss of biota to minor adjustments to organism development, reproduction, and mortality rates (Hodson and Spargue, 1998). Whether or whether trace metals are necessary for metabolism, all aquatic species absorb them from their food or the surrounding aquatic medium (Rainbow 1997, 2002). Metal bioaccumulation is therefore a useful integrative indicator of organisms' exposure to chemicals in ecosystems. Every metal has the capacity to be harmful.

Because metal accumulation is influenced by a number of factors, including multiple exposure routes, the chemical composition of the surrounding medium, and physiological or biochemical effects on bioavailability, it is therefore closely associated with toxicity (Vijver et al., 2004 and Marsden et al., 2004), albeit in a complex way. Even across closely related species, aquatic creatures may have wildly disparate body concentrations of trace metals despite sharing the same habitat (Luoma and Rainbow, 2005). Metal accumulation levels varies greatly between species and metals, and they are distributed differently throughout bodily tissues and organs.

On a hot plate under the hood, these were broken down using three milliliters of nitric acid and one milliliter of 70% percolic acid. Distilled water was added to the digested sample solution until it reached a volume of 10 ml. Atomic Absorption Spectroscopy was used to evaluate the metal content of these samples. The amount of metal in the aquatic biomass was measured in milligrams per kilogram of dry weight. The effects of heavy metals, such as iron (as $FeSO_4$), copper (as $CuSO_4$), zinc (as $ZnSO_4$), and cadmium (as $CdSO_4$), on test aquatic creatures were also investigated. Separately, they were added to the growing medium at an equivalent concentration of 2 mg/liter. The various metal salts' stock solutions were made in double-distilled water. For 20 days, the organism cultures were subjected to varying amounts of four distinct heavy metals. For every metal concentration, four sets are created for a given time frame, such as five, ten, fifteen, or twenty days. After five days, one set of aquatic biomass is filtered through a sterile, fine-nylon cloth, rinsed twice with distilled water, and dried in an oven set at 1050 degrees Celsius. Using a pestle and mortar, the dry sample was ground into a fine powder. To estimate Zn, Fe, Cu, and Cd, a weighted quantity of powder was utilized. Distilled water was used to digest these to a level of 10 ml. Atomic Absorption Spectroscopy was used to evaluate the metal content of these samples. The amount of metal in the aquatic biomass was measured in milligrams per kilogram of dry weight. The process was carried out for 5, 10, 15, and 20 days, in that order. As is well known, copper is a necessary trace metal that is involved in cellular respiration and serves as a cofactor for several critical proteins. One of the main sources of copper for aquatic life is diet. The findings showed that up to 0.05 ppm of copper is absorbed by aquatic biota. Although aquatic biota can absorb up to 0.058 parts per million of cadmium, cadmium is harmful and not necessary for nutrition since it interferes with the metabolism of at least three critical metals: iron, zinc, and calcium. It is a pervasive environmental contaminant.

An crucial component for regular physiological processes is zinc. It plays a crucial structural and catalytic role in about 300 proteins that are involved in immunological, visual, and growth, reproduction, and development processes. Zinc uptake by aquatic biota can reach 0.060 ppm. Iron has been used by aquatic organisms for respiration, photosynthetic processes, and the reduction of nitrogen gas (denitrogen), nitrate, nitrite, and inorganic nitrogen species. Without a question, the most significant and adaptable trace element for biological catalysis is iron. Aquatic organisms can absorb up to 0.059 parts per million of iron. The findings showed that copper, zinc, and cadmium uptake come after iron. Tables 25–28 show the outcomes of heavy metal uptake.

RESEARCH METHODOLOGY

Study Area:
The Damodar River is a tributary of the Damodar River that flows through Jharkhand's, Ramgarh district.

Collection Of Water Samples:
Monthly sampling was done at the Ramgarh, Jharkhand's chosen sample locations. Studying the water quality indicators and the effects of heavy metals on the aquatic biota of Ramgarh, Jharkhand was the primary goal of the sampling process. The study of physico-chemical analysis is crucial to understanding the properties of the water sample. The different physico-chemical characteristics were examined in the gathered samples. During the three years between 2019 and 2022, water samples were continuously taken from each of the three locations. The samples were gathered in 5-liter containers that had been cleaned and wrapped in polythene. Every sample was examined in accordance with the standard protocol provided by APHA in 1998. Numerous physical-chemical characteristics were examined and documented. Chlorides, sulphates, nitrites, dissolved oxygen, conductivity, pH, total dissolved solids, total hardness, chemical and biochemical oxygen demand, heavy metals, and aquatic biota identification were among the parameters measured during the project. This will facilitate statistical analysis and modeling, which will aid in determining water quality and line treatment.

Identification Of Aquatic Biota -
Compared to lakes, rivers have far less dense colonies of plankton or aquatic biota. Since it takes very little time for a given amount of water to move from its source to the sea, there is not enough time for a large number of plankton to multiply. The quantity and quality of plankton vary greatly from headwater to outflow, and the plankton of rivers at different levels differs from one another.

DATA ANALYSIS

To acquire a sense of the data's spread, the annual mean, standard deviation, and percentage coefficient of variation for each parameter were calculated, along with the lowest and greatest values. There were notable temporal and geographical differences. The yearly mean concentrations measured at each site serve as the primary basis for discussing the spatial variations.

RESULTS AND DISCUSSION

The enrichment factor (EF), which is a measure of the organisms' uptake of metals, can be computed using the formula below:

$$EF = \frac{\text{Metal in Aquatic Biota}}{\text{Volume of Aquatic Biota}} \text{ X } \frac{\text{Water Volume}}{\text{Metal in Water}}$$

The findings indicate that the four metals' EF values differ from one another. Iron has an enrichment factor of 73.75, while cadmium has a value of 60. The enrichment factor is 33.33 for copper and 48.33 for cadmium. According to the results, copper has the lowest EF and iron the highest.

Water pollution is one of the major issues facing the planet today. It is mostly due to industrialization and the population's quick and rising increase. Due to unplanned urbanization and the rapid expansion of industries, river pollution in India has now reached a crisis level (Saksena et al., 2008). Numerous scholars have studied river water quality in various locations, and each location has given it more attention. A healthy and long-lasting life depends heavily on the quality of the water. Studying the relationships between many factors is a great way to further research and discover new areas of knowledge. The spectrum of uncertainty related to decision-making is decreased by the study of correlation. The correlation coefficient statistical method was used to analyze the water quality indicators. The correlation coefficient (r) indicates the capacity to predict one variable from another and characterizes the strength of the relationship between two interdependent variables. The following formula can be used to determine the correlation coefficient index (r):

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

where n is the number of variables or data, and x and y are variables. They could have a positive or negative correlation with one another. The range of the correlation coefficient is always -1 to +1. A common tool for determining the strength of a linear relationship is the Pearson correlation coefficient. An association is said to be closer to a perfect linear relation if the correlation is closer to +/-. Tables 4.28–4.36 show the Pearson's Correlation coefficient values (r) between the different water quality metrics of sampling Sites A, B, and C for the years 2019–2022.

At site A (1), temperature has a positive correlation with conductivity, sulphate, phosphate, nitrate, DO, COD, and BOD during the 2019–2022 period. (2) In 2021–2022, conductivity had a negative correlation with pH, TDS, hardness, chlorides, DO, and BOD, while conductivity has a positive correlation with pH, TDS, chlorides, DO, and COD. (3) Hardness, chlorides, sulphate, DO, COD, and BOD all have favorable correlations with pH. (4) TDS has a positive correlation with BOD, nitrate, hardness, and chlorides. (5) Chlorides, sulfate, phosphate, nitrate, DO, COD, and BOD all have favorable correlations with hardness. (6) DO and BOD have a positive correlation with chloride. (7) Phosphate, nitrate, DO, BOD, and COD all have favorable correlations with sulphate. (8) Nitrate, BOD, and COD have favorable correlations with phosphate. (9) DO, BOD, and COD have favorable correlations with nitrate. (10) DO and BOD and COD have a favorable correlation. (11) Over time, there is a positive correlation between COD and DO. (12) Temperature, TDS, pH, hardness, chlorides, sulphate, phosphate, nitrate, and DO all have positive correlations with BOD. From 2009 to 2012, site A shows a strong link between pH and DO, DO and COD, phosphate and conductivity, and nitrate and COD.

Table: 1 Shows aquatic organisms observed during the year 2019 – 2020

Sr. No.	Name of the Aquatic Organisms	Pre - Mansoon			Mansoon			Post - Mansoon		
		Site - A	Site-B	Site-C	Site - A	Site-B	Site-C	Site - A	Site-B	Site-C
1	Anabaena	*	*	*	–	–	*	–	–	–
2	Ceriodophonia	*	*	*	*	–	–	–	–	–
3	Closterium	–	*	*	–	–	*	*	–	–
4	Coelastrum	*	*	*	–	–	–	–	–	–
5	Daphnia	*	*	*	*	*	*	*	*	*
6	Navicula	–	*	*	–	–	*	–	–	–
7	Spirogyra	*	*	*	*	*	*	*	*	*
8	Spirulina	–	*	*	–	*	*	–	–	*
9	Synedra	*	*	–	*	–	*	–	–	–
10	Volvox	*	*	*	*	*	*	*	*	*
11	Chlorella Sp.	*	*	–	*	*	–	–	–	–
12	Oscillatoria anqustissima	–	–	*	–	–	*	–	–	–

Note: - + indicate presence of aquatic organism.
-indicate absence of aquatic organism

Table:2 Shows heavy metals observed during the year 2019 – 2020

Sr. No.	Heavy Metals	Pre - Mansoon			Post - Mansoon			Mansoon		
		Site-A	Site-B	Site -C	Site-A	Site-B	Site - C	Site-A	Site-B	Site - C
1	Copper (Cu)	0.001	0.01	0.01	0.001	0.001	0.001	0.001	0.001	0.001
2	Chromium (Cr)	0.006	0.007	0.006	0.001	0.002	0.002	0.001	0.001	0.001
3	Lead (Pb)	0.005	0.005	0.006	BDL	0.275	0.22	BDL	0.270	0.235
4	Cadmium (Cd)	0.005	0.005	0.007	0.001	0.001	0.002	0.001	0.001	0.001
5	Nickel (Ni)	0.021	0.017	0.020	0.015	0.010	0.018	0.017	0.016	0.022
6	Mercury (Hg)	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
7	Iron (Fe)	0.20	0.14	0.32	0.31	0.001	0.340	0.21	0.150	0.310
8	Manganese (Mn)	0.410	0.530	0.565	0.460	0.421	0.571	0.460	0.400	0.50

Table: 3 Shows Uptake of Iron on Aquatic Biota.

Sr. No.	No. of Days	Heavy metal concentration added (mg) per lit.	Sample taken for uptake analysis (ml)	Heavy metal presents before experiment	Uptake of heavy metal after experiments
1	5	2	200	0.02	0.010
2	10	2	200	0.02	0.021
3	15	2	200	0.02	0.040
4	20	2	200	0.02	0.048

Table: 4 Shows Uptake of Zinc on Aquatic Biota.

Sr. No.	No. of Days	Heavy metal concentration added (mg) per lit.	Sample taken for uptake analysis (ml)	Heavy metal presents before experiment	Uptake of heavy metal after experiments
1	5	2	200	0.03	0.021
2	10	2	200	0.03	0.027
3	15	2	200	0.03	0.036
4	20	2	200	0.03	0.050

Table: 5 Shows Uptake of Cadmium on Aquatic Biota.

Sr. No.	No. of Days	Heavy metal concentration added (mg) per lit.	Sample taken for uptake analysis (ml)	Heavy metal presents before experiment	Uptake of heavy metal after experiments
1	5	2	200	0.03	0.030
2	10	2	200	0.03	0.030
3	15	2	200	0.03	0.040
4	20	2	200	0.03	0.047

Table: 6 Shows Uptake of Copper on Aquatic Biota.

Sr. No.	No. of Days	Heavy metal concentration added (mg) per lit.	Sample taken for uptake analysis (ml)	Heavy metal presents before experiment	Uptake of heavy metal after experiments
1	5	2	200	0.01	0.010
2	10	2	200	0.01	0.020
3	15	2	200	0.01	0.027
4	20	2	200	0.01	0.030

CONCLUSION

Six heavy metals—Zn, Cu, Cd, Pb, Cr, and Ni—accumulated in the body tissues of river fish, Arius sp., according to a research. It has also exceeded the allowable limit.

Twenty-four kinds of plankton were found in the research sites: seventeen species were zooplankton and seven species were phytoplankton. Several indices, including the Simpson dominance index, Shannon Wiener diversity index, Pielou's evenness index, and Margalef species richness index, were used to do community structure analysis. According to these indices, the degree of physico-chemical variables and, therefore, the degree of inorganic pollution in the river significantly influenced the variety and richness of plankton.

Therefore, it is recommended that every wastewater treatment facility include a bioremediation unit in order to lower the pollutant load before release. Additionally, this will assist in recovering the heavy metals from the effluent, which would otherwise be squandered and harm the environment. For the preservation of human life and to preserve the balanced aesthetic value of religious buildings, the water quality at the mouth of the Damodar River must be regularly monitored. To strengthen environmental protection in this area and control the environmental threats caused by these factors, strict law enforcement is required. Reduced effluent discharge from industry and agriculture can be achieved via the development of new technologies and appropriate knowledge transfer.

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