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Discovering Copper Uptake in Aquatic Organisms by Analytical Chemistry and Study of Bioaccumulation, Toxicity, and Ecological Implications

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ABSTRACT

Copper is an essential trace metal, but in elevated concentrations, it can be toxic to aquatic organisms. Understanding its uptake, bioaccumulation, and ecological effects is crucial for assessing environmental health. The concentrations of heavy metal Copper (accumulation) in Tilapia fish organs (muscle, gills, kidney and liver) were investigated. Fish organs from Varal Devi Lake showed greater concentrations of studied metal than those from the standard value.The amount of copper absorbed by kidney is much higher than the other organs. The order of organs infected by Copper metals are as follows.

Kidney>Liver>Gills = Abdominal Muscles

Kidney and Liver of Tilapia contained the highest concentration of the detected heavy metal, while muscles and gills exhibit the same amount and least amount of absorption. This study were carried out during the Ganesh Chaturti festival period as this lake is used for Idol immersion activity. Tilapia caught from this Lake may pose health hazards for consumers.

Introduction:

Various analytical techniques are used for heavy metal estimation. These techniques are Spectroscopic Methods like Atomic Absorption Spectroscopy (AAS), commonly used for measuring copper concentrations in tissues and water samples. Inductively Coupled Plasma Mass Spectrometry (ICP-MS), provides high sensitivity and can detect trace levels of copper in biological samples. Chromatographic Techniques, High-Performance Liquid Chromatography (HPLC), used for separating copper complexes in water samples and understanding speciation. Electrochemical Methods, Voltammetry, enables the detection of copper ions in situ and can provide insights into bioavailability (1,2).

Bioassays involve utilizing model organisms (e.g., fish, crustaceans) to study the effects of copper exposure, allowing for the assessment of bioaccumulation and toxicity. Bioaccumulation in which aquatic organisms uptake copper through gills and skin, and it can accumulate in tissues, leading to higher concentrations than in the surrounding environment.

Factors Influencing Bioaccumulation are species specificity, different organisms have varying capacities for copper uptake.

Environmental conditions like pH, salinity, and organic matter can affect copper bioavailability and accumulation. Toxicity involve physiological effects in which high copper levels can cause oxidative stress, impair gill function, and disrupt enzyme activity. Sublethal effects involves changes in behavior, reproduction, and growth rates can occur even at non-lethal concentrations, impacting population dynamics. Ecological implications involve food web dynamics in which bioaccumulated copper can move up the food chain, affecting predators and altering community structures. Biodiversity loss describe sensitive species may decline, leading to reduced biodiversity and ecosystem resilience. Long-term effects involve chronic exposure can result in population declines, affecting the overall health of aquatic ecosystems (2,3,4).

Copper is required in small quantity by all animals and human being.It is naturally found in many plants and animal, soil, rock.It is also applied in industries for manufacturing different copper based products such as utensils, electrical wiring, construction material, in metal alloy. For the good health, small amounts of copper is required. But excess amount of copper and other form or other compounds of copper causes health problems (5,6,7).

High concentration of Cu enter in to the water by farming and industrial waste water, manufacturing operation discharges into the lake and river water body. Copper may enter in to the drinking water also. Major concern of entry of copper in to the water is through the corrosion of pipes (8).

Contamination from the metals Lead, Nickel, Zinc, Cadmium and copper can harm organisms at low concentration if the metals compounds are in the bioavailable form. It causes ecological effects through biomagnifications. Coppers bioavailability and toxicity to the aquatic animals and organisms can vary depending on the water bodies. It tends to be more toxic and may be more bioavailable in water bodies that are low and dissolved metals or minerals. Hydra animals specially accumulated copper through their food. Copper can be highly toxic at low concentration to invertebrates and to fish in early life stages and may result in food web disruption (1,9).

The main source of copper is from metal wiring, metal pipes, faucets and metal alloys, added as preservatives in the wood, added in water for reducing the excess algal growth, used in leather, fabrics, in agricultural insecticides and fungicides, discharge of industrial and sewage sludge, fertilizer and pesticide residues(5,10).

Source of Copper pollution is from metal painting, plating and mineral leaching into waste water.It is an essential trace element not very toxic to animals, toxic to plant and algae at moderate levels and harmful to human beings at high levels.

Copper sulphate is extremely harmful to fish. Even at low concentration of application,this may creat toxic effects to trouts and fishes in acidic soft water.With increase in the water hardness,its toxicity to fish get decreased. As compared to young fish,the eggs of fish get destroyed by the copper toxicity

Following are the toxic effect of copper on human being at a concentration of 12.0mg/Kg. Irritating and burning effects on gastrointestinal tract, causes unconsciousness, brain injury, kidney, liver and intestine damage, burning pain on skin, ingestion poisoning, itching of skin, allergic reaction in skin, inflammation and conjunctivitis in the lining of eyelid, deterioration of tissues in the cornea (5,11,12).

Methodolgy:

Series of standard solution of various concentrations of copper is prepared. Copper form yellow colour complex with sodium diethyl dithiocarbamate. All the water samples formed yellow complex. This yellowish brown coloured complex is extracted in chloroform in separating funnel. Lower yellowish brown colour organic layer is removed from the separating funnel. Upper aqueous layer is discarded. Organic layer is transferred back to the separating funnel and to the organic layer, 5% H_2SO_4 was added and solution is agitated. The yellowish brown layer becomes more distinct due to this washing with 5% H_2SO_4. The absorbance of this organic layer is taken on Spectrophotometer at 435nm. Blank is also given the same treatment (13).

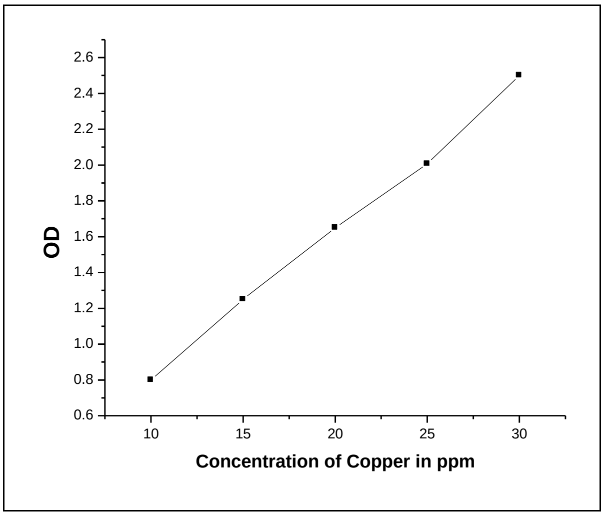

Figure: Graph of OD Vs Concentration of Copper in ppm

The extracted copper present in the fish organs react with Sodium diethyl dithiocarbamate in basic media and yellowish brown complex is formed. EDTA is used to remove the interference. The yellowish brown complex is extracted into chloroform and the absorbance was measured spectrophotometrically at the same wavelength (13).

Result and Discussion:

Table: Amount of Copper

Sr. No.	Periods	Amount of Copper in µg/g of dry fish organs				FAO (1983) µg/g
		Liver	Kidneys	Gills	Abdominal Muscles	
01	Before Immersion	290.446	102.72	20.833	30.0	30.0
02	During Immersion	1315.7	423.0	180.24	31.35	
03	Post Immersion	1522.826	1500.294	296.170	49.307	

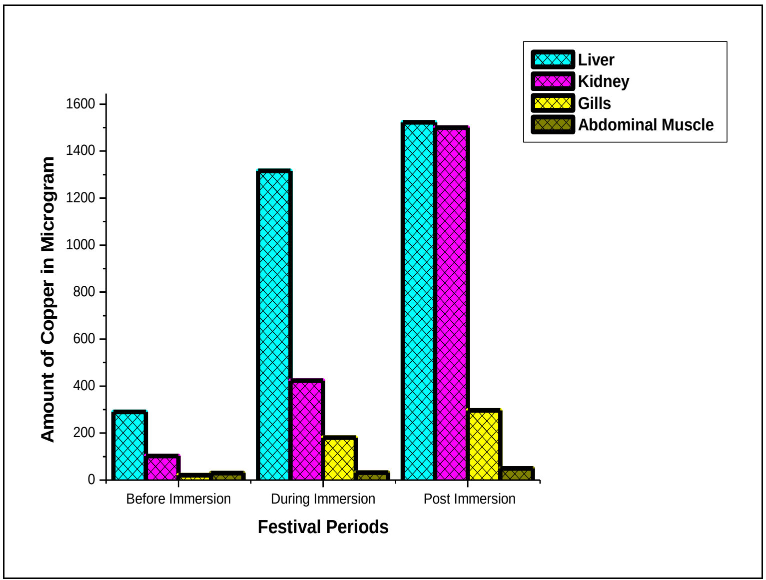

Figure: Amount of Copper Vs Festival Periods

It was observed that the amount of Copper in the fish organs like liver increased from 290.446 µg (before and during immersion activities) to 1522.0 µg (post immersion activities). In the kidneys it increased from 102.72 µg to 1500.0 µg, in the gills from 20.833 µg to 296.170 µg and in the abdominal muscles it increased from 30.0 µg to 49.307 µg. The order of infection of organs by heavy metals was as follows:

Liver>Kidney>Gills>Abdominal Muscle

The amount of Copper in all four fish organs were found to be greater than the standards prescribed by Food and Drug Administration (30 µg/g dry weight of fish organ).

Conclusion:

The level of Copper in liver, kidneys, gills and abdominal muscles were found to be greater than the standards prescribed by FAO.

Because copper is widely present in aquatic settings, frequently as a result of mining, industrial processes, and natural sources, research on its absorption by aquatic species is important.

Copper bioaccumulation in a variety of aquatic animals, such as fish, molluscs, crabs, and algae, has been the subject of numerous research. In order to comprehend how copper builds up within food chains and ecosystems, these investigations track the concentration of copper in various organism tissues throughout time.

Effect on Physiology: Studies have looked into the effects of copper absorption on aquatic organisms' physiology and general health. This covers how it affects oxidative stress, enzyme activity, reproductive success, and the organisms' general fitness(14,15,16,17).

Toxicity Studies: At low concentrations, copper is a necessary element, but at higher amounts, it can be harmful to aquatic life. The goal of toxicity research is to identify the threshold concentrations at which different aquatic species and habitats are adversely affected by copper.

Environmental conditions: Research frequently takes into account environmental conditions such water pH, temperature, salinity, and the presence of other contaminants that can affect copper absorption. These elements have a major impact on copper's toxicity and bioavailability to aquatic life(18,19).

Differences by Species: The tolerance and sensitivity of various aquatic species to copper exposure differ. Understanding species variations in copper absorption, bioaccumulation, and detoxification processes is a common area of research.

Ecological Implications: There are wider ecological ramifications to comprehending how aquatic creatures absorb copper. It aids in evaluating the possible dangers of copper pollution to aquatic ecosystems, including the impact on ecosystem functioning, biodiversity, and the services that aquatic habitats offer (20,21,22).

Regulatory Considerations: Environmental rules and guidelines for the management and control of copper pollution are developed in part by research findings on the absorption of copper by aquatic species. These rules are intended to shield human health and aquatic ecosystems from the negative consequences of copper pollution (23,24).

Research on how aquatic organisms absorb copper offers important information about the environmental fate and impacts of copper in aquatic environments, which influences scientific knowledge and regulatory choices.

Keeping an eye on copper uptake and its ecological effects is crucial for aquatic environment management. By using reliable analytical methods, conservation initiatives and legislative actions can be guided by the evaluation of copper's bioavailability, accumulation, and toxicity in aquatic species (25,26,27).

References:

1) Das K. K, Panigrahi T, Panda R.B, (2012), Idol Immersion Activities Cause Heavy Metal Contamination in River Budhabalanga, Balasore, Odisha, India, International Journal of Modern Engineering Research (IJMER), 2(6), 4540-4542.
2) L. Ramesh Babu & K.Kiran,(2014), Determination of copper in various environmental samples using 4-dimethyl amino benzyl thiourea following solid phase extraction, Journal of Chemical, Biological and Physical Sciences,4(1), 057-062.
3) Vogel's G . H . Jeffery , J . Bassett , J . Mendham, R . C . Denney, A text book of quantitative chemical analysis, Fifth edition, 591-607, ELBS Publication.
4) Khan.F.R., Bury.N.R. and Hogstrand.C.,(2012), Copper , zinc detoxification in pulex ,The J. of Exp. Biology, 215, 822-832.
5) U.S. EPA (2007). Method 200.8: Determination of Trace Elements in Waters and Wastes by ICP-MS.
6) ASTM International. ASTM D1688: Standard Test Methods for Copper in Water.
7) De A. K., Environmental Chemistry, International (P) Ltd, Publishers: Fifth edition New Age.
8) Welz, B., & Sperling, M. (1999). Atomic Absorption Spectrometry, 3rd ed. Wiley-VCH.
9) Skoog, D. A., Holler, F. J., & Crouch, S. R. (2014). Principles of Instrumental Analysis, 6th ed. Cengage Learning.
10) Sindhu,P.S., Environmental Chemistry , New Age International Publisher , Chapter Water Pollution, 54-59.
11) Angelova M., Asenova S.,(2011),Copper in the Human Organism, Trakia Journal of Science,9(1),88-98.
12) Kaur R. D. O,(2013), Comparison of immersion effects of idols made of different materials on the water quality parameters, Indian journal of Fundamental and applied life sciences,l3(1),16-23.
13) D. Rekha, K. Suvardhan, K. Suresh Kumar, P. Reddyprasad, B. Jayaraj and P. Chiranjeevi, (2007), Extractive Spectrophotometric Determination Of Copper In Water And Alloy Samples With 3-Methoxy-4-Hydroxy Benzaldehyde-4-Bromophenyl Hydrazone (3,4-Mhbbph), Serb. Chem. Soc.72 (3), 299–310.
14) Andrew D.E., AWWA Chair,Lenore .S.Clesceri, WEF, EugeneW. Rice, APHA, ArnoldE.Greenberg.Std methods for Examination of Water and waste water, APHA, AWWA, Water Environment Federation (2005) (21sted.).
15) Handy, R. D. (2003). Chronic effects of copper exposure versus endocrine toxicity: two sides of the same toxicological process? Comparative Biochemistry and Physiology Part A, 135(1), 25–38.

16) De Boeck, G., et al. (2010). Copper toxicity in fish: mechanisms of toxicity and protective responses. Aquatic Toxicology, 97(2), 131–139.
17) Clearwater, S. J., Farag, A. M., & Meyer, J. S. (2002). Bioavailability and toxicity of copper and zinc to fish. Environmental Toxicology and Chemistry, 21(11), 2308–2318.
18) Yilmaz, F. (2009). The comparison of heavy metal concentrations (Cd, Cu, Mn, Pb, and Zn) in tissues of three economically important fish species.Turkish Journal of Science & Technology, 4(1), 7–15.
19) Xue, H., & Sigg, L. (1993). Free cupric ion concentration and Cu(II) speciation in natural waters. Aquatic Sciences, 55, 269–287.
20) Davison, W., Zhang, H. In situ speciation measurements of trace components in natural waters using thin-film gels. Nature 367, 546–548 (1994). https://doi.org/10.1038/367546a0
21) Marczenko, Z. (1986). Spectrophotometric Determination of Elements. Ellis Horwood.
22) Van Leeuwen, H. P., Town, R. M., Buffle, J., Cleven, R. F. M. J., & Davison, W. (2005). Dynamic speciation analysis and bioavailability of metals in aquatic systems. Environmental Science & Technology, 39, 8545–8556.
23) Buffle, J., & Horvai, G. (Eds.). (2000). In Situ Monitoring of Aquatic Systems: Chemical Analysis and Speciation. Wiley.
24) Canli, M., & Atli, G. (2003). The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species.Environmental Pollution, 121(1), 129–136.
25) Grosell, M., & Wood, C. M. (2002). Copper uptake across rainbow trout gills: mechanisms of apical entry.Journal of Experimental Biology, 205, 1179–1188.
26) Hogstrand, C., & Haux, C. (1991). Binding and detoxification of heavy metals in lower vertebrates.Comparative Biochemistry and Physiology Part C, 100(1–2), 137–141.
27) USEPA (2007). Aquatic Life Ambient Freshwater Quality Criteria—Copper.United States Environmental Protection Agency.