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Quantitative Determination of Heavy Metals in the Water Samples of Four Fresh Water Ponds of a Mining Town

Payal Banerjee [1], Bably Prasad [2]
[1] *Department Of Applied Chemistry, Central University Of Jharkhand, Ranchi, Jharkhand-835205, India*
[2] *Natural Resources And Environment Management, CSIR-CIMFR, Dhanbad, Jharkhand-826015, India*
Corresponding Author: Payal Banerjee 1

Abstract: *Quantitative investigation of two harmful heavy metals namely copper (Cu) and zinc (Zn) in the water of four most popular lakes of Dhanbad city namely: Bekar Badh lake, Ranitalab lake, Sri Sri Kali Mandir lake, and Bartand Badh lake have been carried out using atomic absorption spectroscopy (AAS). Calibration of the instrument was done using the standard solution. We have compared the obtained data of concentration of Zinc and Copper metal in water of these lakes with the standard maximum permissible limiting value set by Bureau of Indian Standards (BIS) IS:10500 Drinking Water Specification, 2004, considered fit for drinking by humans. The analysis showed that the concentration of heavy metals copper and zinc in four of the above mentioned lakes are much lower than the permissible limit prescribed by BIS and hence do not pose any direct threat to human life on consumption. We have also pointed out the factors responsible behind such contamination and identified the ways to control the contaminant in these water bodies.*

Keywords – *Analysis, Concentration, Heavy metals, Atomic absorption spectroscopy (AAS)*

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I. Introduction

Environment pollution is a matter of big concern in the present day scenario in the world. In pursuance of technologic development for the well-being of human society willingly or unwillingly we have rendered our earth unfit for human survival. Therefore, any unwanted and undesirable change in physical, chemical and biological characteristics of air, water and soil is termed as environmental pollution. Pollutants can be found in any form such as chemical substances or energy such as noise, heat or light. They can be found in any form such as foreign substance or energies or any naturally occurring contaminants such as heavy metal contaminant.

Heavy metals are usually present in traced amounts in natural water sources such as ponds, lakes along with underground water sources. Some of the heavy metal ions are very toxic even at low concentration[1] for human beings. Metals which are reported to be having an adverse effect on human beings are arsenic[2], lead[3], cadmium[4], nickel, mercury[5], chromium, copper, zinc, and selenium. These metal ions are increasing day by day in the natural resources as currently numbers of industrial complexes are increasing near human population[6] in cities with a goal of improving the quality of human life. These contaminants are increasing in water bodies which are a natural source of drinking waters. The increase in concentrations of contaminants in water bodies is due to their discharge through industrial wastewater, without any proper pre-treatments. Metals also have a critically important role in flora and fauna. Their oxidation or reduction states are of particular importance for controlling various physio-chemical processes going inside plants and animals. They play an important role inside plants and animals so that they can escape control mechanisms such as transport, homeostatic, compartmentalization and binding to required cell constituents. But during such ongoing processes inside plants and animals these metals bind with protein sites which are not made for them by displacing original metals in a competitive process. These displacements of original metals from their actual sites cause the cell to malfunction leading to toxicity[7] in plant and the human body. In support of this phenomena research has revealed that oxidative deterioration of biological macro molecules is primarily due to binding of heavy metals to the DNA and nuclear proteins.

Chronic and acute high dose of copper is suicidal for a human being particularly from the view point of gastro intestinal (GI) disorder. The GI disorder includes GI mucosal ulcers, internal bleeding, haemolysis, hepatic necrosis accompanied with jaundice, nephropathy, cardiotoxicity with hypertension, headache, central nervous system manifestation including dizziness, headache, convulsions and even coma. Copper does not only have harmful sides for a human being but it also has vital importance directly linked with human life as it is the key constituent of respiratory enzyme complex cytochrome oxidase. Copper is mainly found in the humans in the liver, muscle and bones.

Zinc is considered one of the most essential elements with exceptional biological importance especially for its role in prenatal and post-natal development in a human being. Deficiency among children can cause a variety of syndromes such as diarrhea, susceptibility to infectious microbes, delayed sexual maturation and retardation of growth. Zinc also has been reported to have anti- oxidant property that delays the ageing effect in humans. Zinc has also been found to have an important role in injury healing in a human being. Although not well established zinc is also thought to have a beneficial effect on the human immune system. Zinc consumption in doses above than recommended can lead to a zinc induced copper deficiency in a human being.

In our present study we have studied the water samples of four major popular fresh water lakes namely: Bekar Badh lake, Ranitalab lake, Sri Sri Kali Mandir lake, and Bartand Badh lake of Dhanbad so as to quantitatively determine the concentration of the two major heavy metal mentioned above. We have selected these four lakes as they are considered as the alternative source of water by Dhanbad municipality. The aim of our study was to ascertain whether the water of these four fresh water lakes are fit for human consumption or not as an alternative source and free from the toxicity of heavy metals like copper and zinc.

II. Experimental Section

2.1 Chemicals required: One litre of water from each of the mentioned lakes located in the city of Dhanbad, Nitric acid (2% v/v), certified 1000 ppm AAS standards (Zn, Cu) samples for AAS calibration, Petridis, beaker, filter paper, water bottles, gloves, funnel, measuring cylinders and distilled water are required.

2.2 Collection of samples and experimental procedures: 1 litre water samples from each of the four fresh water lakes were collected from random positions of the lakes mentioned above in standard laboratory water bottles. From the collected water samples 500 ml of water was then filtered by using Whatman 42 filter paper. In the 500 ml filtered water few drops of concentrated nitric acid HNO_3 was added to turn the water sample acidic preferably to a pH value of less than 2. HNO_3 is added to samples for two purposes. One, below pH 2, precipitation, adsorption to container wall and microbial degradation is minimized. Though any acid will serve the purpose, HNO_3 is preferred because of its oxidizing nature. Adding HNO_3 converts metal ions into their nitrate salts, which are highly soluble. Sample digestion is required before AAS[8] analysis. The purpose is to destroy the matrix, which otherwise interferes during atomization. Also digestion converts all form of metal into a single oxidation state. The choice of the acid mixture depends on the organic matter content and turbidity of the sample. Water having turbidity <1 NTU can be analysed without digestion. Addition of Conc. HNO_3 acid is required to preserve the water samples to minimize metal cation precipitation and adsorption onto the sample. Moreover, heavy metal ions in trace levels may be adsorbed by the glass. Hence, the nitric acid additional role is to prevent the adsorption of metal ions on glass along with the above mentioned reasons. After that the sample was heated in a hotplate, for several hours till the whole sample becomes 10 times concentrated than the parent sample. Thereafter, the sample was again filtered through whatman 42 filter paper and stored in a 50 ml volumetric flask. The data attached below was acquired by AAS[9] spectrophotometer using air-acetylene flame after calibration by copper standards of 1ppm, 3ppm, 4ppm, and 5ppm concentrations. For zinc analysis, standard solutions of zinc were prepared, using 0.4ppm, 0.8ppm, 1.2ppm, and 1.5ppm of zinc solutions.
For performing atomic absorption spectroscopy of liquid samples following two steps were done to make the samples ready for investigation. They are as under:

2.2.1. Atomization of the samples: The solution is drawn through a capillary tube and taken to the burner with the help of nebulizer where the solution is broken up into a fine mist. The mist is carried to the atomizer just as a flame carried by a carrier gas. When the mist reaches the flame intense heat breaks up the sample into its individual atoms. This final process is called atomization.
Once the sample reaches the flame three more steps occur- desolvation, volatilization and dissociation. First a molecular aerosol is produced when the solvent evaporates (desolvation), then the aerosol is formed into gaseous molecules (volatilization) and finally the molecules dissociate and produce atomic gas (dissociation). During this process cations and electrons can also be formed when the atomic gas is ionized. A mixture of different oxidants and fuels can be used to achieve a specific temperature range. Because dissociation and breaking of molecules are easier with more heat so, oxygen is the most common oxidant used in flame atomization. Usually the flame consists of an excess of fuel to prevent oxides from forming with the molecules of the sample.

2.2.2. The absorption of radiation from the light source by the free atoms: The electrons of the atoms in the atomizer can be promoted to higher orbitals (excited state) for a short period of time (nanoseconds) by absorbing a defined quantity of energy (radiation of a given wavelength). This amount of energy, i.e., wavelength, is specific to a particular electron transition in a particular element. In general, each wavelength corresponds to only one element, and the width of an absorption line is only of the order of a few picometers (pm). The radiation flux without a sample and with a sample in the atomizer is measured using a detector, and the ratio between the two values (the absorbance) is converted to analyte concentration or mass using the Beer-Lambert Law.

2.3. Instrumentation: Thermo scientific M5 series Atomic absorption spectrophotometer is used to analyse the water samples of the lakes of Dhanbad for quantitative determination of the presence of heavy metals preferably Copper and Zinc in it. The calibration curves were generated using a standard solution of the copper and zinc metals by following the procedure given in the manual and thereby using appropriate detectors in the wavelength range suitable for quantitative determination of the concentration of copper and zinc in the water of four lakes of Dhanbad city. Repetition of the experiment for accurate determination of the concentration of copper and zinc metal presence in water was done to ensure minimization of experimental errors.

III. Results And Discussions

The investigation of the collected water samples from four most popular fresh water source in Dhanbad city for the presence of zinc and copper heavy metal was done by AAS spectrophotometer at CSIR-CIMFR, Dhanbad reveals that the concentration of the metals- zinc and copper are within permissible limit which is considered as fit for human consumption as per Bureau of Indian Standards (BIS), IS: 10500, Drinking Water Specification, 2004. The concentration of metals e.g. copper and zinc in four of the water ponds are listed below in the table. Comparison of the obtained data with the BIS standard for drinking water is also highlighted in the table below.

The primary source of copper in water is from industrial waste, water pipelines inserted in ponds for water pumping, from corrosive metal waste dumps inside water bodies, utensils made of copper, fertilizer containing copper, copper sulphate etc. The major source of zinc in water is leaching of zinc from piping and fittings. The copper contamination can be reduced if certain easy steps are followed i.e. washing of utensils of kitchen and household made of copper is prohibited strictly by local villagers.

Although the concentration of metals such as copper and zinc are within permitted limit range prescribed by BIS the matter of concern is that Bekar Bandh lake which is nearest among four lakes under study has highest zinc and copper metal concentration which points towards the fact that the city dumps wastes into the water bodies which need to be prohibited as early as possible. Moreover the colony residence and the temple authorities should also restrain from dumping household and temple waste into the water of Bekar Bandh lake to keep its water healthy.

Sri Sri Kali Mandir lake has least human population beside it possesses least copper and zinc metal contaminant which confirms the role of city people in increasing the metal concentration in water which in long run will make these lake water unfit for human consumption even as a secondary source of water.

Table: Concentration of Zinc and Copper metal in water bodies of Dhanbad city in mg/l

Name of water ponds	Concentration of Zinc	IS: 10500: Desirable limit of zinc	Concentration of Copper	IS:10500: Desirable limit of copper
Bekar Badh lake	0.036	5.0	0.011	0.05
Rani Talab lake	0.026		0.007	
Sri Sri Kali Mandir lake	0.015		0.003	
Burtand badh lake	0.020		0.006	

Based on the above observation it can be considered that Bekar Badh lake water of Dhanbad city is not contaminated with respect to copper when the quality of pond water is compared with IS: 10500, Indian Drinking Water Specification. The water of all the lakes is within a limit with respect to copper and zinc. The trend shown in the table above is shown in the fig.1 below. Another important point to note from the above presented data is that the lakes which have greater human resident around it tends to have more metal contamination than with the least population around it. The human population density around these lakes are in sequence: Bekar Badh lake> Rani Talab lake> Burtand Badh lake> Sri Sri Kali Mandir Lake which is similar to the sequence in which concentration of heavy metal concentration in these lakes increases i.e. Bekar Badh lake> Rani Talab lake> Burtand Badh lake> Sri Sri Kali Mandir Lake. These prove the role of the city population in increasing metal contamination in these lakes. This trend also led us to the inference that the fresh water lake close to the center of the city of Dhanbad tends to have higher metallic zinc and copper concentration than that of the lakes 1.5-2 km away from the center of the city. The trend has been shown in fig.2 below which shows the variation of copper and zinc concentration in mg/l in water of these four lakes with varying distance of their locations from the center of the city of the mining town, Dhanbad.

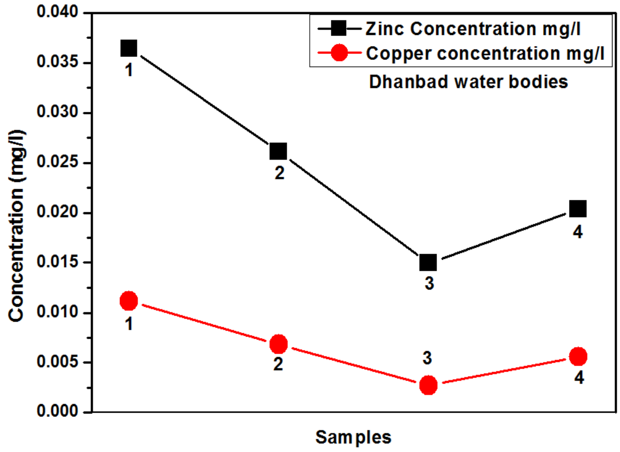

Figure. 1: The curve shows the amount of copper and zinc in four lakes of Dhanbad numbered as (1) Bekar Badh lake, (2) Rani Talab lake, (3) Sri Sri Kali Mandir lake, and (4) Burtand badh lake.

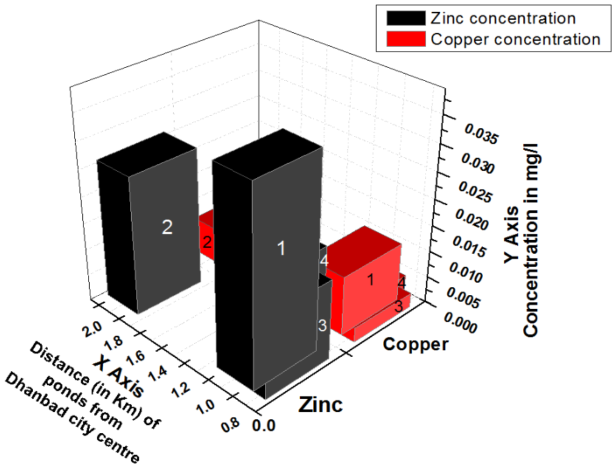

Figure. 2: The 3-D bar diagram shows the amount of copper and zinc in four lakes of Dhanbad numbered as (1) Bekar Badh lake, (2) Rani Talab lake, (3) Sri Sri Kali Mandir lake, and (4) Burtand badh lake and their distance from centre of the Dhanbad city also known as the coal capital of India.

IV. Conclusions and future prospect

The investigation of water samples collected from a natural source of water in Dhanbad city reveals that atomic absorption spectroscopy is an extremely potent tool to identify metal presence in water which is considered as an alternate source of drinking water by the population in and around Dhanbad. We have found out that the copper concentration level of all the four water bodies of Dhanbad city is within a desired permissible level which is rendered fit for consumption as an alternate source of drinking water. The investigation also established the direct role of human involvement in heavy metal contamination in these lakes. The investigation report suggests that the water bodies of Dhanbad are safe from copper and zinc contamination until now so prohibition of dumping garbage, fertilizer, batteries, replacement of water pipelines in these lakes are of utmost importance to prevent further copper contamination. Consumption of fishes of these lakes is also safe for the local population. Time to time evaluation of metal presence must be done to keep an eye on the improvement or degradation in the quality of water in these lakes. Immersion of deities of goddess during the festive season must also be strictly prohibited as they heavily degrade the water qualities as they contain paint, chemical, copper wire, iron nail and many toxic materials which are non-biodegradable. It is up to the people of Dhanbad to maintain a clean and green environment in their own city to add days to their life. Only a vigilant population of Dhanbad can maintain the environment quality.

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