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Analysis of heavy metal accumulation in water and fish (*Cyprinus carpio*) meat from Umiam Lake in Meghalaya, India.

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Abstract

Water quality around the world is notably declining mainly due to human activities. Low lying water catchment areas are under considerable threat of accumulating higher pollutants including heavy metals due to natural drainage and upstream anthropogenic activities. The major group that gets affected is the aquatic animals. Bioaccumulation of toxic metals in these organisms causes potential threat to human health upon consumption as these metals tend to get biomagnified in higher trophic levels within a food web. Umiam reservoir in Meghalaya is of significant importance to the state as it is the source of hydel power generation and is a popular destination for water sport and adventure facilities. Downstream irrigation, fisheries and drinking water from the lake cater to local anthropogenic needs. In recent times due to the rising population in the capital Shillong which is situated upstream of the lake, the lake is becoming significantly polluted. With this background the present study was aimed at determining the level of heavy metals in water samples of the Umiam lake as well as in the most dominantly occurring fish species, *Cyprinus carpio* found in the reservoir that is widely consumed. Presence of metal ions was determined using atomic absorption spectroscopy that uses different lamps specific to a metal ion in the sample. The sequence of metal concentrations (in ppm) in the water sample was found to be Se (1.39) > Mn (0.186) > Fe (0.12) > Pb (0.06) > Cd (0.045) > Zn (0.031) > Cu (0.023) > Cr (0.016) > Ni (not detected). Comparing these values with WHO guidelines it was found that the levels of Se and Pb in the waters of the lake are significantly higher than the recommended values [for Se (0.04) and Pb (0.01) respectively]. A similar assessment conducted on fish meat collected from the lake showed high accumulation of Se (1.58 ppm) in the fish muscle. The order of occurrence of other metal ions in the fish muscle was Se>Zn>Fe>Ni>Cu>Cd~Mn>Cr>Pb revealing that if concentration of metal ions such as Zn, Fe, Cu goes up in the water, these ions would get preferentially accumulated in the fish muscle. The higher concentration of Se in the water as well as in the fish meat confirms bioaccumulation of this element. Although selenium is an essential trace element required in the human diet for synthesis of selenocysteine, high concentration in the body may lead to chronic selenium toxicity that manifest as selenosis, a condition associated with changes to the hair and nails, skin lesions and clinical neurological effects. Therefore, consumption of fish meat from the lake over a prolonged period of time may lead to biomagnification of this metal in human increasing the risk of chronic selenium toxicity. This study is important in bringing about awareness to general population about potential dangers of being exposed to continuous heavy metal toxicity, specifically those using this water from the lake for drinking.

Keywords: Heavy metals; Atomic absorption spectroscopy; Umiam reservoir; *Cyprinus carpio*.

INTRODUCTION

Pollution of water bodies is becoming a major cause of concern with respect to human health [1]. Various anthropogenic activities, domestic and industrial effluents lead to degradation of the quality of both natural and man-made water bodies [2]. Increase in the human population has greatly contributed towards the conversion of these water bodies to impending contamination sinks [3]. Aquatic environments particularly lakes and reservoirs located near industrial or urban areas are potential targets for the flow of environmentally harmful elements such as organic and inorganic contaminants. One such group of contaminants or aquatic pollutants is the heavy metals. Heavy metals are well known to be non-biodegradable and when present at high concentrations, they tend to bioaccumulate [4]. They can cause a variety of ailments in humans depending on the degree of exposure. These vary from minor skin irritation to severe damages of the liver, kidney, nerve tissues and circulatory system. For example the trace element selenium (Se) is required in small amounts, but overexposure can cause selenium accumulation in living tissues leading to health problems such as hair and fingernail loss, fatigue, irritability and on chronic exposure can damage kidney, liver tissues, circulatory and nervous system [5]. Similarly, although zinc (Zn) is an essential requirement for good health, excess zinc can be harmful. Zinc toxicity can occur in both acute and chronic forms. Acute adverse effects of high zinc intake include nausea, vomiting, loss of appetite, abdominal cramps, diarrhea, and headaches. Chronic effects include copper deficiency, altered iron function, reduced immune response, and reduced levels of high-density lipoproteins. Drinking water contaminated with manganese (Mn) has been associated with neurological and behavioural effects. There is an association between manganese accumulation and liver disease. Acute nickel (Ni) exposure is associated with a variety of clinical symptoms and signs which include gastrointestinal

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disturbances, visual defects (temporary left homonymous hemianopia), headache, giddiness, wheezing and cough. Long-term exposure to cadmium (Cd) is associated with renal dysfunction, obstructive lung disease, lung cancer and bone defects (osteomalacia, osteoporosis) in humans. Copper (Cu) is an essential element to human life, but in high doses it can cause anemia, liver and kidney damage, and stomach and intestinal irritation. Exposure to lead (Pb) at high dose manifests as toxic biochemical effects in humans causing problems in the synthesis of hemoglobin, affecting kidneys, gastrointestinal tract, joints and reproductive system, and nervous system [6,7,1]Thus, these metals can lead to long-term toxic effects in the biological systems even if they are present in insignificant amounts and may get transferred to other organisms through the food chain [8, 9]. The presence of heavy metals in contaminated water bodies may pose a threat to the existing ecosystem of an area as a whole [10, 4, 3]. When an aquatic water body is contaminated, fishes which are present at the top of an aquatic food chain, bioaccumulate most of the toxic substances present in the contaminated water body. In environmental studies, fishes have been used by scientists to assess the health of aquatic habitats. Since fishes form a major part of the human diet, concern over the presence of elevated levels of heavy metals in their bodies has become significant [11, 12, 10]. Assessment of toxic heavy metals in the fishes can thus give an insight to the degree of pollution of a particular water body in an area [13].

Meghalaya, (latitude 20° 1' N & 26° 5' N, longitude 85° 49' E & 92° 53' E) a state in the north-eastern part of India extends for about 300 kilometers in length and about 100 kilometers in breadth. Meghalaya's capital, Shillong and also the District Headquarters of East Khasi Hills District is situated at an altitude of 1,496 meters above sea level. The state has an area of 22,429 km^2. and enjoys a temperate climate which varies with altitude and is uniquely cool all year through with maximum temperature of around 25° and minimum of 1° or 2°. It is one of the most beautiful hill stations in the country [14]. The state gets abundant rainfall, has large forests area, waterfalls, rivers and numerous other water bodies.

The Umiam lake is located 15 km downstream from Shillong. It originated as an artificial reservoir for the first hydel project in the Northeast. The lake is one of the major tourist spots of the state. Two streams i.e, the Umkhrah and Umshyrpi are connected to it as they cut through the bustling city and merge together to form the Wah Ro-ro stream which joins the Umiam river thereby forming the main source of water for the Umiam lake. In recent times, rapid urbanization of the adjoining areas has led to rise in contaminants in these two rivers. Such polluted river waters enter Umiam and make the water quality unfit for any domestic use except irrigation without conventional primary treatment. However, villagers living around Umiam lake regularly use water from this lake for drinking and all other domestic activities. Selling fish caught from the lake is a major commercial activity among the villagers.

The present work is a case study where accumulation of some heavy metals commonly found in the waters of the Umiam lake was examined in the fish species i.e. *Cyprinus carpio* found in the lake.

MATERIALS AND METHODS

Fish samples of the species *Cyprinus carpio* (common carp) were bought from the fishermen who freshly caught the fish in the early morning hours and then identified with the help of an expert zoologist. The fish samples were dissected to procure the muscle samples for analysis. The muscles were then placed in petridishes and oven dried to remove water content. The dehydrated samples were then prepared for heavy metal analysis by atomic absorption spectroscopy. Use of atomic absorption Spectroscopy in determination of metal ions is a well standardized and precise protocol that determines metal ions in parts per million (ppm concentration) or in other words in micro quantity in a given sample. For each metal ion to be determined, a specific lamp is used. This is a highly reliable technique and is followed worldwide for determination of metal ions in minute concentrations.

Wet Ashing Method: 0.5 g of the dried fish muscle tissue was placed in 125 ml Erlenmeyer flask with glass beads and 25 ml of deionized water. To this, 10 ml of a 1:2 mixture of concentrated HNO_3 and $HClO_4$ was added. The sample was boiled until the solution was clear. The clear solution was transferred to a 50 ml volumetric flask and the volume doubled with deionized water and mixed. All the heavy metals were assayed using atomic absorption spectrophotometer Model: Perkin Elmer 3110 housed in the Sophisticated Analytical Instrumentation Facility (SAIF), North Eastern Hill University Campus, Shillong and the results were determined in ppm. Data were analyzed in duplicates. For the water sample, 500 ml water was concentrated to 50 ml at 40°C.

RESULTS

Fig. 1 and Fig. 2 shows the concentrations of the various heavy metals i.e, Cd, Zn, Ni, Mn, Se, Cr, Pb, Fe and Cu in the water and soil samples collected directly from the Umiam lake. In the water sample the heavy metals were found to be in the following order of increasing concentrations Se (1.39) > Mn (0.186) > Fe (0.12) > Pb (0.06) > Cd (0.045) > Zn (0.031) > Cu (0.023) > Cr (0.016) > Ni (not detected). Selenium constituted the major portion of concentration of the total metal ions determined. Selenium was 74% followed by 10% of manganese and 7% of iron. Occurrence of other heavy metals in the water sample from the lake was not so significant.

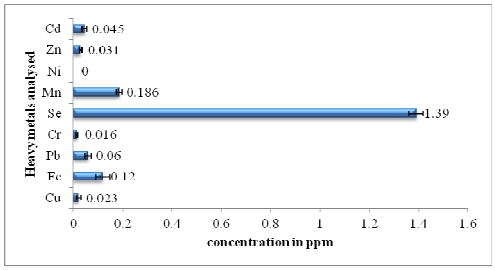

Fig 1. Heavy metal content in water samples from Umiam lake

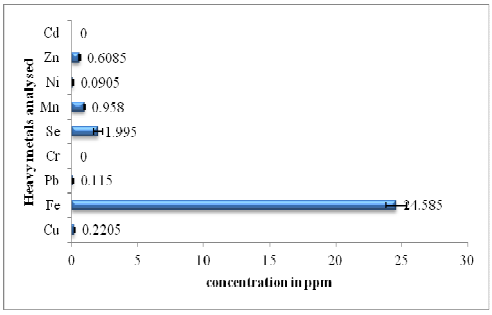

Fig 2. Heavy metal content in soil samples from Umiam lake

In the soil samples, the values (in ppm) of the metal ions were in the order of Fe (24.58) > Se (1.995) > Mn (0.958) > Zn (0.6085) Cu (0.2205) > Pb (0.115) > Ni (0.0905) > Cd & Cr (ND). 86% of iron was found deposited on the soil followed by selenium 7%, manganese 3% and zinc 2%.

Fig. 3 shows the accumulation of heavy metals in the muscle samples of *Cyprinus carpio* in the order Se>Zn>Fe>Ni>Cu>Cd~Mn>Cr>Pb with highest accumulation of selenium (47%) followed by zinc at 34% and iron at 17%.

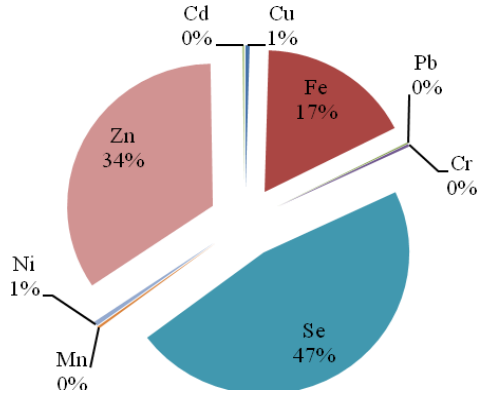

Fig 3. Heavy metal content in fish samples from Umiam lake

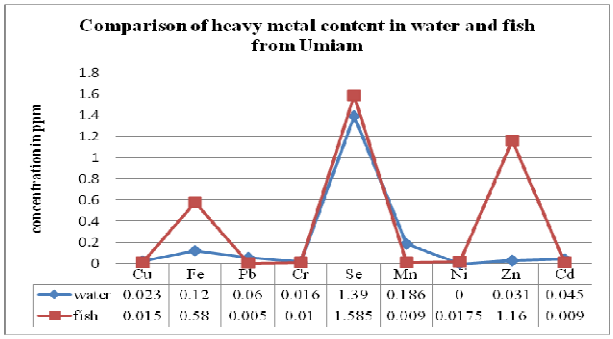

Fig 4. Comparative analysis of heavy metal presence in water and fish meat from Umiam lake

A comparative analyses of heavy metal concentration in water and fish from the Umiam lake showed that only three metals i.e., selenium, zinc and iron were selectively accumulated by the fish from the water of the lake. Of these zinc and iron seem to be of much concern since Zn accumulation is 37 times of that of what exists and in water and Fe is 5 times in the same scale.

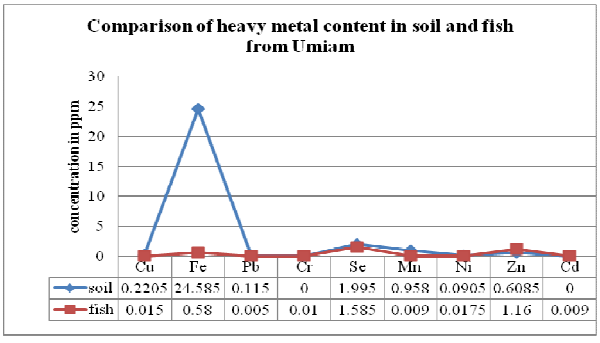

Fig 5. Comparative analysis of heavy metal presence in soil and fish meat from Umiam lake

Comparison of levels of heavy metals in soil and fish from the lake showed no significant bioaccumulation of metal ions could be attributed to the metal ions that were deposited on the soil bed of the lake.

DISCUSSION

Pollution of water bodies is a matter of utmost concern especially if it is located near residential areas. Meghalaya is very rich in various mineral resources and coal being one of the major resources. The state has an estimated coal reserve of 559 million tones, which are spread over in an area of 213.9 km^2 covering approximately 1% of the total geographical area of the state [15]. Continued mining activities combined with a wide range of human anthropogenic activities have lead to the degradation of a major section of the state's important water bodies. Few decades back, the two streams i.e., the Umkhrah and Umshyrpi which form the main source of water for the Umiam lake, flowed with sparkling clean water that was safe for drinking, fishing and other activities like swimming. However, recently the Central Pollution Control Board (CPCB) has confirmed that the water in these two rivers is contaminated with sewage and levels of contamination with various pollutants have reached significant level in these waters. There is concern over bioaccumulation of these pollutants such as heavy metal ions in the aquatic organisms especially in fish as they are consumed by humans and thus are in risk of getting exposed to these harmful pollutants. It is already known that the bioaccumulation of heavy metals in organisms tends to occur when they take them in from their surrounding environment and retain them in their bodies [16]. Comparing the recorded values with WHO guidelines it was found that the levels of Se (1.39), Pb (0.06) and Cd (0.045) ppm in the water from the lake are significantly higher than the recommended values [for Se (0.04), Pb (0.01) and Cd (0.003) ppm respectively]. However, a similar experiment with the fish muscle tissue showed only high accumulation of Se (1.58 ppm) and not those of Pb and Cd. Even though other metal ion concentrations in the fish muscle were within the limits of permissible values, Se bioaccumulation was more than 5 times the permissible amount in the fish meat (0.32 ppm) [5]. Thus, Se accumulation in these fishes that form part of almost every day diet of the local population is a matter of alarm and therefore such information should be made available to the concerned people those who could be affected by overexposure to Se on a regular basis. They should also be taught to recognize early symptoms of such metal toxicity.

CONCLUSION

This is a case study involving the presence of heavy metal contaminants in the waters of Umiam lake. Presence of such pollutants were also assayed in the fish *Cyprinus carpio* commonly found in the lake and forms a major component in the everyday diet the local population. In this study the heavy metals Se, Pb and Cd were found to be higher than the recommended value by WHO for drinking water. Thus there is a threat of overexposure to these metal ions in the population who uses this water for drinking. Se was also found to be selectively bioaccumulated in the fish muscle, thus increasing the level of such exposure. This could raise the possibility of disorders caused by metal toxicity in the population that are exposed to the high levels of these metal ions on a daily basis.

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