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Advances in Applied Science Research, 2014, 5(4):56-62

ISSN: 0976-8610
CODEN (USA): AASRFC

Bioaccumulation of alkali and alkaline earth metals (sodium, potassium, calcium and magnesium) in fish (*Labeo rohita* Ham.) organs from selected districts of Odisha, India

A. Mallick*[1,2], B. C. Mohapatra[2] and N. Sarangi[2]

[1]Department of Environmental science, University of Kalyani, Nadia, West Bengal, India
[2]Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, India

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ABSTRACT

The bioaccumulation of alkali and alkaline earth metals such as sodium, potassium, calcium and magnesium were estimated in five different organs i.e., tissue, kidney, gills, liver, and testis/ovary of rohu, Labeo rohita (Ham.). The samples were collected from three study areas namely Kendrapada (KPD), Keonjhar (KEO) and Central Institute of Freshwater Aquaculture (CIFA) in Odisha. There was recorded a large variation in accumulation of metals in different tissues. The content of metals in gonads was estimated lower compared to other tissues. The pooled data for all the stations revealed that, in different organs the content of sodium (102±2.190 to 64±1.303), potassium (3.6±0.031 to 2.31±0.572), calcium (17.42±0.618 to 9.88±1.406) and magnesium (20±1.095 to 10±1) ppm respectively in wet wt. But in water medium the contents of sodium, potassium, calcium and magnesium were 7.6±0.712 to 7.2±2.002, 14.3±1.463 to 12.8±2.037, 2 1.92±0.494 to 17.06±3.495 and 20±1.233 to 18.3±2.20 2 ppm respectively. The content of calcium, magnesium and potassium in different organs were low in comparison to the water medium. But the content of sodium in different organs was higher in comparison to that of water medium. The content of calcium, magnesium and sodium were recorded higher in body tissue than other organs, but the content of potassium was nearly equal in all tissues.

Key words: Alkali and alkaline earth metals, Rohu, Bioaccumulation, KPD, KEO, CIFA

INTRODUCTION

Bio-accumulation measurements refer to studies or methods monitoring the uptake and retention of pollutants like metals or biocides in organs and/or tissues of organisms, such as fish [1]. It means an increase in the concentration of a chemical substance in a biological organism over time. Bioaccumulation of metals reflects the amount ingested by the animal, the way in which the metals are distributed among different tissues and the extent to which the metals remained in each tissue type.

Water that is transported actively (marine fish) or passively (freshwater fish) into the body due to the difference in osmotic concentration between the external and the internal environment may also contribute to the uptake of metal ions from water during lifetime of a fish. It is well documented that pollutants, such as metals and organic compounds can be accumulated by aquatic biota [2]. Bioaccumulation measurements refer to studies or methods monitoring the uptake and retention of these pollutants in organs and/or tissues of organisms, such as fish [3]. This can only take place if the rate of uptake by the organism exceeds the rate of elimination [4].

The term bio-uptake describes the processes by which the substance is actually taken into the body of the fish. The amount that is actually accumulated will depend on the balance between uptake rate, metabolism of the chemical and excretion rate [5]. [6] further indicated that bio-uptake kinetics gives information on how fast chemicals are taken up. It is generally recognized that there are three possible routes for a substance to enter a fish: gills, food and skin. Owing to direct contact with ambient water, gills are proposed to be the first and most important targets of waterborne metals [7, 8, 9]. Several studies also claimed that the major route of bio-uptake for metals that concentrate in fish is across the gill epithelium [10, 11].

Freshwater fish can and do accumulate calcium directly from the water by absorption across the gills [12, 13, 14] and in at least some species of fish this mode of calcium accumulation is sufficient to maintain normal growth, even when the fish are fed a calcium-deficient diet [15, 16, 17, 18]. In fact, even when calcium is supplied with the food, direct absorption of calcium from the water *via* the gills prevails [19]. Fish accumulate metals in its tissue from polluted environment. Metal distribution between different tissues of fish varies depending on the sources of uptake, diet and\ or water borne exposure [20]. Among fish species, considerable differences in sensitivity to metals have been reported.

MATERIALS AND METHODS

Collection of tissue samples from field

Four surveys were conducted in Kenrdpara (KPD), Keonjhar (KEO) and Central Institute of Freshwater Aquaculture (CIFA) during July, October, January and April of 2007-08. Five ponds were selected from each study areas. They are in Kendrapada, Keonjhar and Khurda Districts of Odisha (Fig 1). Five matured fish from each pond were collected during each survey. They were stored in a cooler packed with ice box in order to maintain the freshness and latter transported to the laboratory for dissection of the organs.

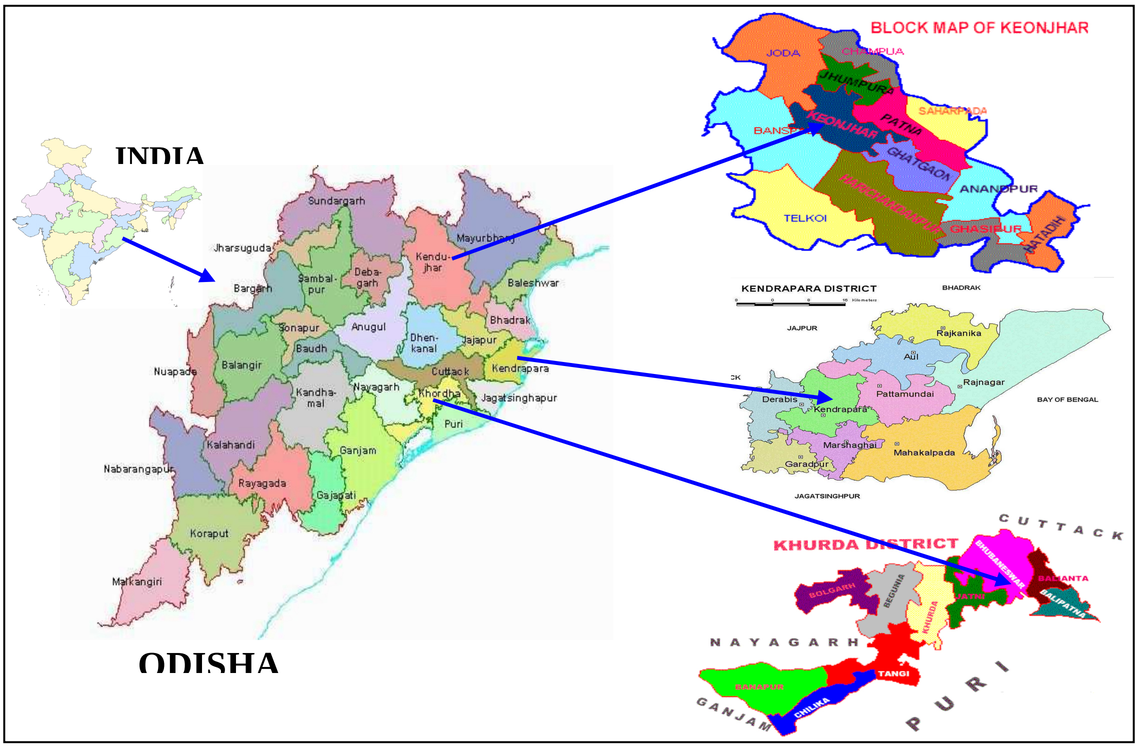

Figure: 1 Map showing study locations

Sample digestion and estimation

One gram of each organ (tissue, kidney, gills, liver, and testis/ovary) ware taken and placed into digestion flasks and predetermined amount of concentrated nitric acid was added to the sample. The flasks were kept in the digestion chamber at 120^{0}C until the vapor and the acid fluids inside the flask turned clear. After completion of the digestion process, the samples were cooled and filtered using Whatman filter paper No 42, and the final volume made up to 25 ml with distilled water. The samples were kept in airtight amber colored glass bottles for determination of the metal concentrations. The concentration of metals was determined using Systronics Flame Photometer (Model 128). Initially the Flame Photometer was calibrated using standard concentrations of sodium, potassium and calcium metal solution then reading was taken. Magnesium was estimated by EDTA titration methods [21].

RESULTS AND DISCUSSION

In this work, we also observed the trend that different metals are accumulated at different concentration in various organs (Fig. 2-5).The difference in the levels of accumulation in different organs of a fish can primarily be attributed to the differences in the physiological role of each organ. Other factors such as regulatory ability, behaviour and feeding habits may play a significant role in the accumulation differences in the different organs [22]. The result of each metal is explained individually.

Sodium

Accumulation of sodium was determined in different organs like tissue, liver, gill, kidney and gonads of rohu from the experimental ponds. In case of CIFA fish tissue the content of sodium was (102±2.190) Kendrapada (66±1.140) and Keonjhar (65±0.547). In case of gill the content of sodium of CIFA was (74±14.060), Kendrapada (65±1.581) and Keonjhar (65±0.447). In case of kidney the content of sodium in CIFA fish (91±31.004) Keonjhar fish was (67±2.302) and Kendrapada fish was (65±1.095). In case of liver the content of sodium of CIFA fish was (101±54.765), Kendrapada (66±1.949) and Keonjhar (65±0.836). In case of testies/ ovary the content of sodium in CIFA fish (101±29.125), Kendrapada fish was (65±1.483) and Keonjhar fish was (64±1.303).

In case of Content of sodium in respective experimental pond water of CIFA was (7.6±0.712), Kendrapada (7.6±0.712) and Keonjhar (7.2±2.002) pond water. From the above result I found that there was no relation was found with the content of pond water and fish body organs. The present results agree with the work of [23] who has reported that the concentration of sodium in fish tissue varied in different test concentrations and no definite relation was obtained.

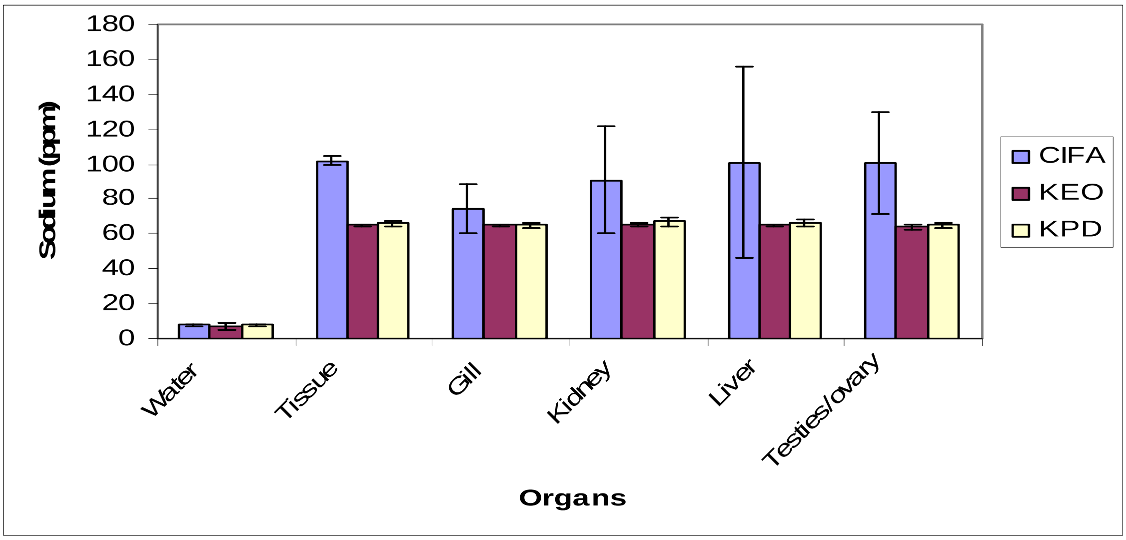

Figure: 2 Bioaccumulation of sodium in different organs of fish

Potassium

Accumulation of potassium was determined in different organs like tissue, liver, gill, kidney and gonads of rohu from the experimental ponds.

In case of CIFA fish tissue the content of potassium was less (2.9±0.170) than Kendrapada (3.17±0.273) and Keonjhar (3.18±0.169). But in case of gill the content of potassium was more (3.1±0.162) than Kendrapada

(2.39±0.638) and Keonjhar (3.49±0.197). In case of liver the content of potassium was (3.55±0.02), Kendrapada (3.18±0.170) and Keonjhar (3.06±0.275). In case of testies/ovary the CIFA fish (2.42±0.375), Kendrapada (2.31±0.572) and Keonjhar was (2.66±393).

The potassium content in respective experimental ponds ware nearly equal. The CIFA pond the content of potassium was (14.3±1.451), Kendrapada (12.8±2.037) and Keonjhar (14.3±1.463) pond water. From the above result I found that there was no relation was found with the content of pond water and fish body organs. The accumulation value of potassium in rohu fry was increased with increase of concentration, higher the concentration value lower the accumulation [23].

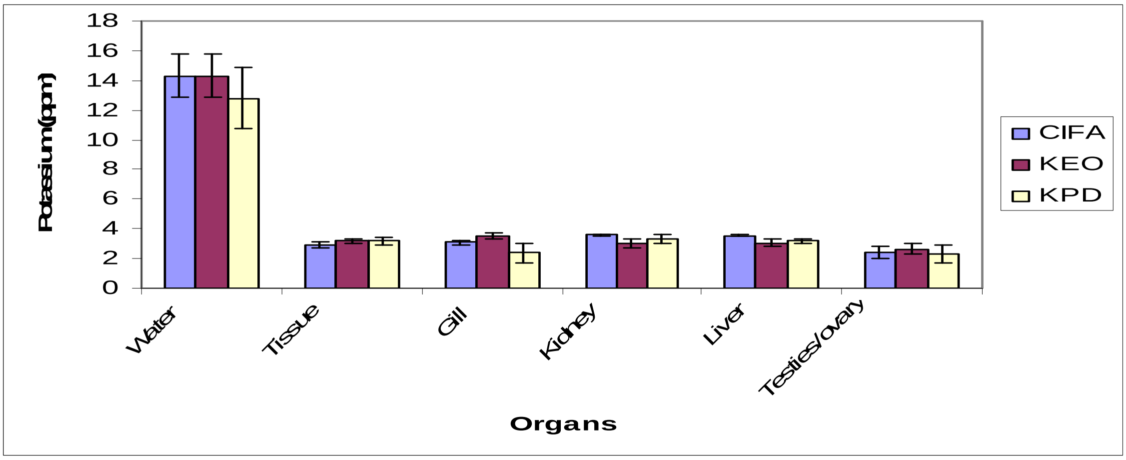

Figure: 3 Bioaccumulation of potassium in different organs of fish

Calcium

Accumulation of calcium was determined in different organs like tissue, liver, gill, kidney and gonads of rohu from the experimental ponds. In case of CIFA pond Content of calcium was higher (21.92±0.494) than Kendrapara (18.96±2.360) and Keonjhar (17.06±3.495) pond water, but accumulation of Calcium in different organs of rohu did not follow the water content. Content of calcium in CIFA pond water was more, but in case of tissue the content of calcium was less (10.56±0.219) than Kendrapara (11.58±0.268) and Keonjhar (15.54±3.605). Higher the calcium content in water results lower the accumulation and lower the calcium content in water results higher the accumulation. But in case of gill accumulation of CIFA fish the content of calcium was less (9.88±1.406) than Kendrapara (11.46±0.328) and Keonjhar (16.08±3.759). Higher the calcium content in water results lowers the accumulation and lower the calcium content in water results higher the accumulation *i.e* (Keonjhar). In case of kidney the content of calcium of CIFA fish was less (11.34±3.100) than Kendrapada (12.24±3.667) and Keonjhar (16.04±3.831). Higher the calcium content in water results lower the accumulation (CIFA) and lower the calcium content in water results higher the accumulation (Keonjhar). In case of liver the content of calcium was less (13.78±5.714) than Kendrapara (11.46±0.801) and Keonjhar (17.3±0.212). Higher the calcium content in water results lower the accumulation (CIFA) and lower the calcium content in water results higher the accumulation (Keonjhar). In case of testies/ovary the content of calcium was less (11.66±3.216) than Kendrapada (11±1) and Keonjhar (17.42±0.618).

In case of CIFA and Kendrapada the calcium content is nearly equal but in case if Keonjhar the calcium content is more. Bioaccumulation has shown trend in fry of rohu. The lowest bioaccumulation (150 ± 8.66ppm) was found in 0.2 ppm and highest accumulation of 360 ± 8.60ppm was found in 2 ppm of calcium solution. The calcium accumulation of advanced fry of rohu increases from 38.33 ± 4.91 to 72.62 ± 1.76 in lower concentration from 0.015 to 150 ppm [23]. There are no available reports elsewhere to compare the present findings.

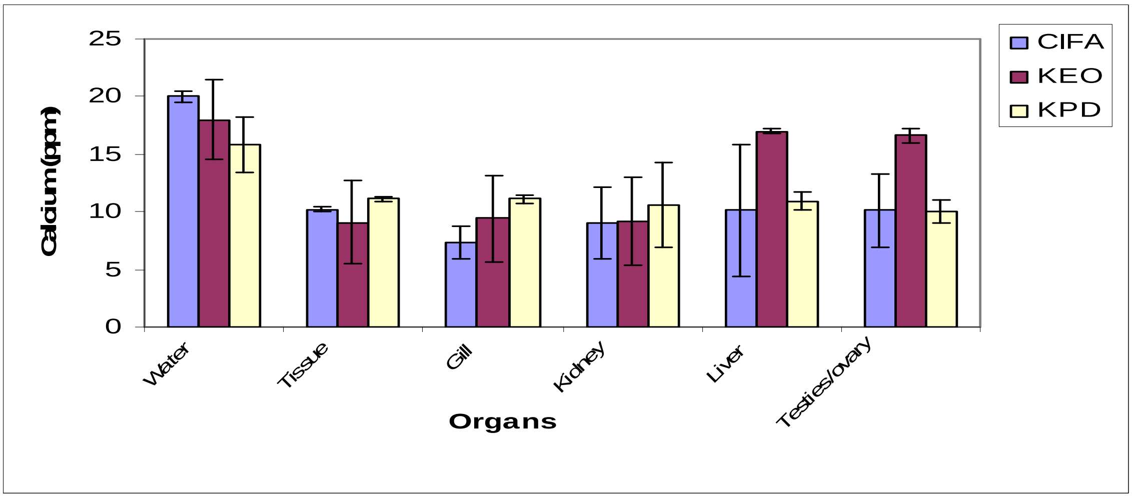

Figure: 4 Bioaccumulation of calcium in different organs of fish

Magnesium
Accumulation of magnesium was determined in different organs like tissue, liver, gill, kidney and gonads of rohu from the experimental ponds. In case of CIFA pond Content of magnesium was higher (20±1.233) than Kendrapada (13.2±5.129) and Keonjhar (18.3±2.202) pond water, but accumulation of magnesium in different organs of rohu did not follow the water content. Content of magnesium in CIFA pond water was more, but in case of tissue the content of magnesium was less (14±1.673) than Kendrapada (20±1.095) and Keonjhar (17±1.625). Higher the magnesium content in water lower the accumulation and lower the magnesium content in water higher the accumulation. But in case of gill the content of magnesium was more (14±0.894) than Kendrapada (12±2.280) and Keonjhar (12±4.147). In case of Kendrapada and Keonjhar the magnesium content is nearly equal but in case if CIFA the magnesium content is more. In case of kidney the content of magnesium was more (10±1.788) than Kendrapada (12±2.280) and Keonjhar (10±0.894). In case of CIFA and Keonjhar the magnesium content is nearly equal but in case if Kendrapada the magnesium content is more. In case of liver the content of magnesium was more (10±1.788) than Kendrapada (10±1) and Keonjhar (12±0.894). In case of CIFA and Kendrapada the magnesium content is nearly equal but in case if Keonjhar the magnesium content is more. In case of testies/ovary the content of magnesium was more (10±1.788) than Kendrapada (10±3.464) and Keonjhar (10±1.414). The magnesium content was nearly equal in each case.

Magnesium bioaccumulation in rohu was maximum in the lowest concentration of NaCl *i.e.*, 0.01 ppm in medium. In case of advanced fry bioaccumulation was increased from lower concentration to higher one in the rearing medium [23].

When fish are exposed to elevated levels of metals in the aquatic environment, they can absorb the bioavailable metals directly from the environment *via.*, gills and skin, or through the ingestion of contaminated water and food. Metals in the fish are then transported by the bloodstream, which brings it into contact with the various organs and tissues [24]. Fish can regulate metal concentrations to a certain extent. The ability of each tissue to either regulate or accumulate metals can be directly related to the amount of the metal accumulated in the specific tissue. Furthermore, physiological differences and the position of each tissue in the fish can also influence the bioaccumulation of a particular metal [25]. Metal distribution and accumulation in different tissues of fish varies depending on the sources, uptake, diet and or water borne exposure [22].

During early life, the yolk sac stage is considered the most sensitive one, followed by the embryonic stage prior to completion of gastrulation [26]. Calcium deficiency includes swelling and poor match ability of eggs and slow development; lack of resistance and low survival of sac fry. Higher calcium concentration protects the fry from ammonia and metal ecotoxicosis. Magnesium is also essential in skeletal tissue metabolism and neuromuscular transmission [27]. Freshwater fish derive magnesium ions by active uptake from the environment or from dietary sources.

Magnesium is an essential nutrient for fish and, although adult fish take up magnesium from the water *via* the gills [28], intestinal magnesium uptake is of primary importance for growth and homeostasis [29]. A significantly higher content of Mg was observed in the muscle of pike [30].

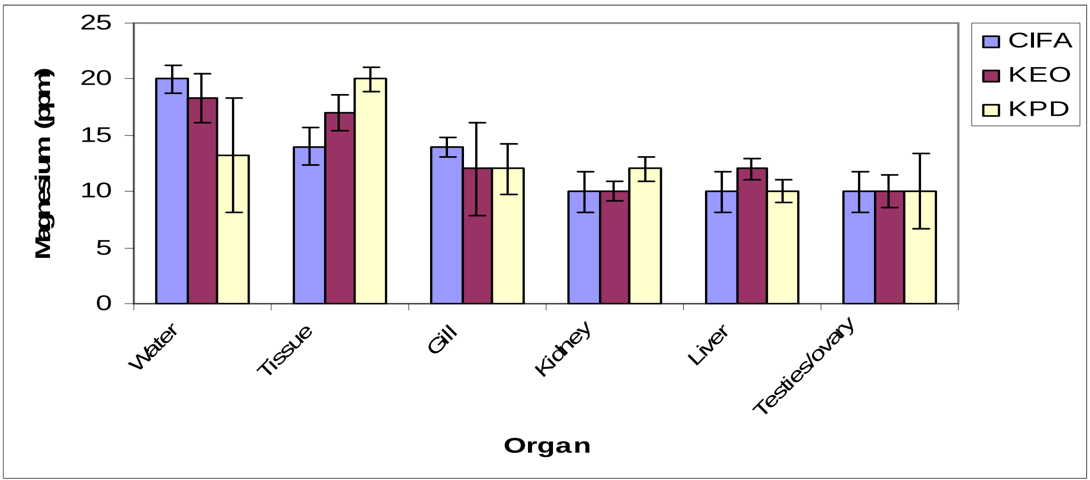

Figure: 5 Bioaccumulation of magnesium in different organs of fish

CONCLUSION

This conforms to the previous studies which revealed that Alkali and alkaline earth metals accumulation in different organs ware varied in different concentration did not follow the water content [23]. These results indicate that the gill is the primary source of metal exposure so the metals were more concentrated in the gills while kidney accumulates least in comparison to the other parts of the fish. The levels of the metals in the organs of fish were different at the different sample stations. Calcium is essential for strong bones and teeth and it regulates the heart rate and nerve impulses. It is an important component of blood clotting. Magnesium assists in the utilization of calcium and potassium, and functions in enzyme reactions to produce energy. Sodium and potassium are electrolytes that must be balanced in the body. Potassium important for a healthy nervous system and a steady heart rate and sodium, is critical in maintaining fluid balance. The study clearly indicated significant accumulation of alkali and alkaline earth metals (sodium, potassium, calcium and magnesium) in the organs of the fish species from different locations (Kendrapada (KPD), Keonjhar (KEO) and Central Institute of Freshwater Aquaculture (CIFA) of Odisha were acceptable. The content of sodium, potassium, calcium and magnesium in the selected areas of fish is safe for health, because the metal content is within the advisable limits.

Acknowledgement

We are thankful to the Director, Central Institute of Freshwater Aquaculture, Bhubaneswar, Odisha, India for providing facilities for research work.

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