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Traditional Aquaculture Practice at East Calcutta Wetland: The Safety Assessment

[1]S Raychaudhuri, [1]M Mishra, [1]S Salodkar, [2]M Sudarshan and [1]A R Thakur
[1]Department of Biotechnology, West Bengal University of Technology, BF-142, Sector 1, Salt Lake, Calcutta-700064
[2] UGC-DAE Consortium for Scientific Research, Calcutta Centre, III/LB-8, Bidhan Nagar, Calcutta-700064

Abstract: The current study is on East Calcutta Wetland (ECW) which is a model for multi-use resource recovery system with activities like pisciculture and agriculture. The entire city's soluble waste is disposed into the raw sewage canals which finally drains into the shallow, flat bottom fish ponds called Bheri. These sewage fed fisheries act simultaneously for the purification process like removal of heavy metals, coliform reduction as well as fish production at a commercial scale. The fishes from these Bheri are analyzed for the extent of metal accumulation in them as compared with those collected from the fresh water ponds around Calcutta. This comparative study was done to access the risk involved, if any, in fish cultivation and its subsequent consumption from these wastewater fed fisheries. Two types of commonly consumed fishes were chosen for the study namely *Labeo rohita* and *Cirrhinus mrigala*. Analysis of elements like P, S, Cl, K, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Br, Rb, Sr and Pb was done by Energy Dispersive X Ray Fluorescence (EDXRF) in order to quantify the level of accumulation. The analysis inferred that elements like Cr, Cu, Rb, Pb shows accumulation in substantial amount in both type of fishes collected from the sewage fed as well as freshwater sources. The uptake of these fishes by human population thereby causes the consumption of these elements in relatively higher level as compared to the Recommended Dietary Allowance (RDA). Thus consumption of waste water cultivated fishes pose no additional health hazard. The accumulation of these metals in fishes from both Bheri as well as fresh water pond put forth a plausible action of diverse microscopic population and certain geochemical factors acting beneath the phenomenon of sedimentation as well as biomagnification of metal in the fish pond and their subsequent uptake in the aquatic food chain.

Key words: EDXRF, ECW, *Labeo rohita*, *Cirrhinus mrigala*, Bheri

INTRODUCTION

Cities consume resources and produce both solid and liquid waste. Waste may normally be defined as any material or energy which cannot be economically used, recovered or recycled at a given time and place. Thus every city of the world must find a way of dealing with its waste. But what if this waste can be treated as a useful resource instead of a hazard to the public? That is exactly the practice developed by the 20,000 natural ecologists, i.e the farmers as well as the fisherman of East Calcutta Wetland. It is because of them that sewage has taken on a new meaning for Calcutta. Natural processes coupled with informal practices contribute significantly to wastewater treatment and promotes recycling. ECW's resource recovery system, developed by local people through the ages, has saved the city of Calcutta from the costs of constructing and maintaining wastewater treatment plants. Calcutta currently has no sewage treatment plant for its 12 million inhabitants. The recycling system that has developed over a century operates with minimum use of technology and engineering [1].

Calcutta's raw wastewater-fed fish pond system, called "Bheri" as well as the Munich's treated wastewater-fed fisheries is frequently cited as showpieces of wastewater-fed fish production. At ECW these are operating very successfully since 1930 and are the worlds largest ensemble of wastewater fisheries covering an area of approximately 4,000 ha and

Corresponding Author: Shaon Raychaudhuri, Lecturer of Department of Biotechnology, West Bengal University of Technology, India, 700064

providing employment to more that 4000 families[2]. Though both treat wastewater but the architecture as well as associated purification mechanism of Bheri is quite different from any other wastewater fed fisheries elsewhere. These are shallow, 50 to 150cm deep, flat bottom ponds which are prepared following certain specific procedure[3]. The shallow depth, immense sunlight, constant aeration due to stirring as well as continuous supply of input (in large bodies) along with algal photosynthetic oxygen release, growth of plankton, introduction of fish at a specific point of plankton growth, the liming of the floor of the pond during preparation and the water hyacinth surrounding the edges together result in the reduction of coliform count up to 96 to 99% and metal content upto 25 to 99% in the Bheri[4]. Being shallow Bheri receives ample solar energy which is trapped by a dense population of plankton which in turn is consumed by the fishes. The plankton play a significant role in degrading the organic matter, but its overgrowth becomes a problem for pond management by causing algal bloom. It is at this critical phase of the ecological process that the fish plays an important role by grazing on the plankton. The two fold role played by the fishes is indeed crucial – they maintain a proper balance of the plankton population in the pond and also convert the available nutrients in the wastewater into readily consumable form (fish) for humans.

Many industries, especially electroplating, battery and plastic manufacturing release heavy metals such as cadmium and zinc in wastewater [5-6]. Mobilization of heavy metals in the environment due to industrial activities is of serious concern due to the toxicity of these metals in human and other forms of life[7-8]. Removal of toxic heavy metals from industrial wastewater is essential from the standpoint of environmental pollution control[9]. Conventional techniques of controlling metal-contaminated water (for example, chemical treatment) are costly in terms of equipment and chemicals. Moreover, they require intensive management and long-term maintenance[10]. . There have been extensive studies on the extent of metal accumulation in different parts of the fishes [11-17]

In this study we attempt to analyze the extent of metal accumulation using EDXRF in the muscles of two specific types of fishes from Bheri. One of them, *Labeo rohita,* is a surface feeder and the other, *Cirrhinus mrigala,* is a bottom feeder. The analysis of these two layers in shallow flat bottom ponds would ensure complete analysis of the entire depth. The reason for considering the muscles is the fact that mainly those are the edible parts and thus accumulation there would result in its direct transfer into the humans through consumption. Moreover it has been shown by previous study that metal accumulation is minimum in muscles as compared to other parts[16]. In this study accumulation is also compared in same species from fresh water fed ponds to assess the risk involved, if any, in growing fishes in raw wastewater fed fishponds as compared to fresh water bodies. This would also help to analyze the effect of geochemical, human activity and microbial action in those locations on metal accumulation in fish muscle.

1. MATERIALS AND METHODS

Sample collection and study area*:* Two types of fish were chosen for the study namely *Labeo rohita and Cirrhinus mrigala.* These varieties were taken from Captain Bheri at ECW and a freshwater pond at Madhyamgram, North 24 Parganas, West Bengal (non ECW site).

Sample preparation*:* The fish were washed with tap water and rinsed with distilled water. The fish were dissected using stainless steel scalpels and forceps. A part of the muscle was removed and washed using distilled water. The washed muscle pieces was taken in cylindrical container for lyophilization. Lyophilization was carried out for a period of two days. The lyophilized material was grinded in a blender. The powdered material was sieved using 100 mm sieve. 200 mg of the sieved material was measured and pellets were made using Pelletizer (110 Kg/cm^2) for EDXRF study. Five replicate pellets of each fish sample were prepared and the study was repeated thrice.

Sample Analysis*:* The elemental compositions of the pellets prepared from fish muscles were determined using EDXRF technique. The procedure for EDXRF analysis carried out in Jordan Valley EX-3600 EDXRF system was same as that used by Ray Chaudhuri elsewhere[18]. The concentrations were measured in µg/g. The quantitative analysis is carried out on line, by the inbuilt ExWin software.

To determine the relative intake per person per day of fish, the net consumption after cooking was determined. From there the corresponding wet weight as well as the dry weight and further the actual elemental concentration in that given amount was calculated. This value was used to determine the daily consumption of a person of the different elements. It was found that 15 gms wet weight yielded 2.5 gms dry weight for fishes. For this study 0.2 gms of dry weight was used for each pellet. So it corresponds to 1.2 gms of wet weight of fishes.

Statistical Analysis and Data Evaluation*:* The Standard Deviation of the data collected was computed using the following equation:

S.D. $=\sqrt{[(X_i - X_m)^2 / (n-1)]}$,

Where Xi denotes the ith observation, X_m is mean of the observations, and n stands for the number of observations.

The mean of the observations was calculated and the difference of each observation from the mean was obtained. Each such difference was squared and the squared values were added to get the sum of squares. This sum was divided by the number of observations minus one to get mean-squared deviation, called variance. The square root of the variance gives us root-mean squared deviation, called standard deviation.

For each set of data, standard deviation (S.D.) was calculated and graphs of elements vs its concentration were plotted using Origin 6.1 software.

RESULTS AND DISCUSSION

It is known that metal concentrations in fishes collected from ECW can be affected by the wastewater treatment. To check the actual contribution of the wastewater treatment, the ECW results were compared with those of Non-ECW. The concentrations for the elements like P, S, Cl, K, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Br, Rb, Sr and Pb were determined by EDXRF.

Table 1: Elemental concentration in µg/gm in muscles of *Labeo rohita*

Element	ECW Mean ± S.D. (µg/g)	Non ECW Mean ± S.D. (µg/g)
Cr	11.78 ± 3.84	4.97 ± 0.93
Cu	971.3±36.57	409.16±21.57
Rb	17.25± 1.09	5.3± 1.117
Pb	3.17 ± 0.57	5.95 ± 1.25

Elements showing appreciable variations between ECW and Non-ECW samples are mentioned in Table 1, Graph 1 for *Labeo rohita* and in Table 2, Graph 2 for *Cirrhinus mrigala*. Cr, Cu and Rb levels are higher in *Labeo rohita* from ECW than those from Non-ECW while Pb is found in higher concentration in Non- ECW sample as compared to ECW. P, Cl, Rb and Pb levels are significantly higher for *Cirrhinus mrigala* from ECW while Ca, Cr and Cu levels are comparatively higher in *Cirrhinus mrigala* from Non- ECW. The above finding was further validated by PIXE analysis (Data not shown).

Table 2: Elemental concentration in µg/gm in in muscles of *Cirrhinus mrigala.*

Element	ECW Mean ± S.D. (µg/g)	Non ECW Mean ± S.D. (µg/g)
P	1280 ± 182.21	259.2± 749.05
Cl	2064.6 ± 59.85	1246.8± 151.03
Ca	250.2 ± 202.97	869.34 ± 29.04
Cr	4.72 ± 0.52	11.09 ± 3.63
Cu	240.9 ± 101.4	1022.3± 146.88
Rb	12.72 ± 1.46	2.107± 0.73
Pb	26 ± 10.36	4.96± 1.1

Table 3: Comparative analysis of daily intake of elements per person through consumption of *Labeo rohita* against the Recommended value

Element	Recommendation (mg/day)	Element in *Labeo rohita* from ECW consumed by 1 person (mg/day)	Element in *Labeo rohita* from Non-ECW consumed by 1 person (mg/day)
Cr	0.05 – 0.2	1.47 ± 0.48	0.621 ± 0.116
Cu	1.5 – 3	121.43 ± 4.57	51.145 ± 2.69
Rb	-	2.156 ± 0.136	0.66 ± 0.14
Pb	-	0.48 ± 0.22	0.74 ± 0.156

The load for Cr comes from tanneries situated around ECW which directly dump their waste to the raw sewage canal which in turn drains into the Bheri. At Non- ECW it mainly comes from pieces of crudely processed leather after manufacturing of hand gloves and bags in the cottage industry. Cu comes from small scale industries involved in electroplating and metal handicraft manufacturing at different places in and around Calcutta. Rb comes mainly from mica that is disposed in the effluents generated by paints used in glow sign, *Gulal* (dry colours containing mica commonly used during festive season in India) manufacturing as well as in thread treatment for flying kites. The source of Pb is from the battery industries,

Table 4: Comparative analysis of daily intake of elements per person through consumption of *Cirrhinus mrigala* against the Recommended value.

Element	Recommendation (mg/day)	Element in *Cirrhinus mrigala* from ECW consumed by 1 person (mg/day)	Element in *Cirrhinus mrigala* from Non-ECW consumed by 1 person (mg/day)
P	700	1410 $\pm$ 22.77	1282.4 $\pm$ 93.63
Cl	750	258.075 $\pm$ 7.48	155.85 $\pm$ 18.88
Ca	1000 - 1200	156.27 $\pm$ 25.37	108.66 $\pm$ 3.63
Cr	0.05 – 0.2	0.59 $\pm$ 0.065	1.386 $\pm$ 0.454
Cu	1.5 – 3	30.11 $\pm$ 12.67	127.79 $\pm$ 18.36
Rb	-	1.59 $\pm$ 0.18	0.26 $\pm$ 0.09
Pb	-	3.25 $\pm$ 1.295	0.62 $\pm$ 0.14

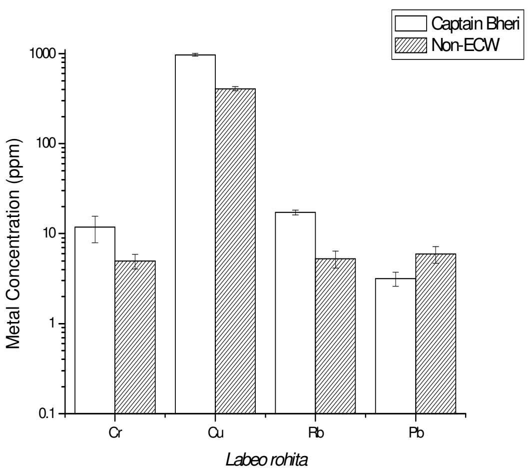

Fig 1: Graphical representation of elemental concentration in µg/gm in *Labeo rohita.*

automobile garages which are there in and around Calcutta. All these are dumped into Bheri along with the waste water. Before sedimentation Cr and Cu are taken up either directly or by surface planktons which are subsequently eaten up by the surface feeders (*Labeo rohita*). This results in greater accumulation in the surface feeders at ECW. Being shallow Rb is distributed along the length (50- 150cm) of the Bheri resulting in their accumulation in both the surface and bottom feeders. Pb being denser starts to sediment and accumulates mostly inside the bottom feeders through plankton as well as directly. P and Cl shows preferential accumulation in *C mrigala* as compared to *L rohita* as it could not be detected in the former during both the analysis (EDXRF and PIXE). On the other hand in the freshwater fed ponds the depth is non uniform. Thus during sedimentation the Pb is taken up by the surface feeders before it could reach the bottom of the pond. It is presumed that the diverse microscopic biota at the freshwater fed pond could be responsible for the sedimentation of metals like Ca, Cr and Cu which is thereby available to the bottom feeders. Richer microbial diversity of the sediment of the fish ponds as compared to the surface water, as observed by Ray Chaudhuri and Thakur elsewhere, validates the above statement[19].

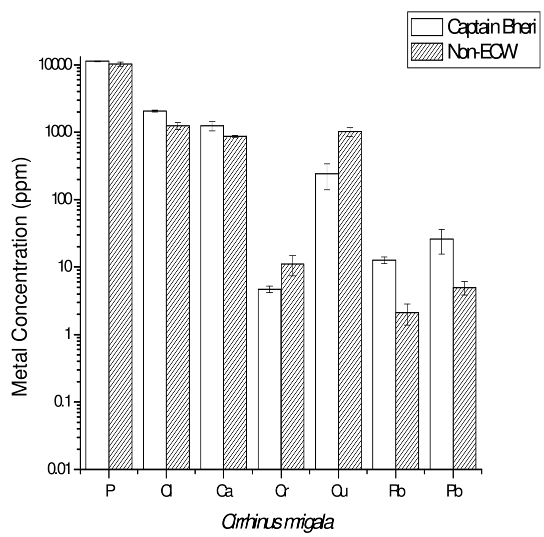

Fig 2: Graphical representation of elemental concentration in µg/gm in *Cirrhinus mrigala.*

Our next objective was to find the amount of element (in mg/day) in fishes consumed by one person. For this it was initially found that 15g wet weight (for *Labeo rohita* and *Cirrhinus mrigala)* gives 2.5g dry weight (for *Labeo rohita and Cirrhinus mrigala*). For this study 0.2g dry weight of the fish were taken to prepare each pellet. That in turn corresponds to 1.2 gms wet weight. Thus the mean value mentioned in the above tables (Table 1, 2) corresponds to 1.2 gm wet weight. From this the amount of element (in mg/day) in fish consumed by one person was calculated assuming that the consumption of fish by an individual per day would be 150 mg. The Table 3 and 4 compares the daily consumption of element through fish with the recommended dietary value.

The results indicate moderately high consumption of Cr as well as P and Cu is much higher as compared to the RDA value. Rb and Pb are not essential for the body but yet are consumed through fishes in substantial amount. Cl and Ca are found to be much below the RDA value.

Thus from the above study we can conclude that wastewater fed fisheries pose no additional threat to the metal accumulation in fishes as compared to freshwater fed fish ponds in these localities. Similar magnitude of elemental accumulation in fishes from both the origins indicates the putative role of microbial participation (biomagnification) along with geochemical factors.

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