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Human Risk Assessment upon Consumption of Cultured Fish from Two Fish Farms in Khartoum State

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Abstract

This study investigated the quantity of four heavy metals namely Aluminum (Al), Manganese (Mn), Cobalt (Co) and Arsenic (As) in fish gills, muscles and bones of two cultured fish Oreochromis niloticus (Bulti), and Clarias lazera (Garmout). As well as estimating the hazard indices when consuming these fish .The fish samples were collected from two farms Alshagara fish farm along the White Nile and and Seleit scheme fish farm along the Blue Nile. An atomic absorption Spectrometry was used to determine the four heavy metals in the different samples of fish. In general the pattern of accumulation of heavy metals in the two fish species from both farms was gills > muscles > bones. Results showed that Al was found in substantial amounts when compared to Co, Mn and As. Investigating the muscles as the edible part by consumers, results showed that Mn and As concentrations of fish species from the two farms were found in higher levels than FAO/WHO [1] standard levels, while Al and Co concentrations in the tested fish were within permissible levels. Hazard index less than one recorded in the study, suggested that consumption of fish with the detected levels was acceptable daily intake to human. It was concluded that there was no any adverse health effects developing due to exposure to these fish species. Also there is an urge to establish suitable Sudanese standards according to Sudanese Demographic profile.

Keywords: *Cultured Fish; Environmental Toxicity; Heavy Metals; Tilapia; Clarias; Khartoum; Sudan*

Introduction

The rapid development of industrialization results in heavy metals pollution, which is a significant environmental hazard for invertebrates, fish, and humans [2,3]. Likewise rapid population growth and industrialization in Khartoum State has contributed to the increased pollution levels on the already overburdened man activities along the banks of both the Blue and White Niles. These factors have contributed to the degradation of their water quality. Degradation of water quality could lead to the degradation of natural resources that could greatly affect the quality of the fish. Additionally, cultured fish may increase risk because recently people consume larger quantities of these fish. Among heavy metals Aluminum (Al) is the third most common abundant metal on earth after oxygen and silicon [4]. It is similar to many other metals in that it is generally considered most toxic in its soluble ionic form [5]. Manganese (Mn) is an essential nutrient to humans [6]. It is a metal having relatively low toxicity to human beings, and causes acute poisoning effect at higher concentrations. Arsenic compounds in the third (III) oxidation state (arsenites) are toxic compounds .They are absorbed rapidly into fish [7]. Another heavy metal of great concern is cobalt, which doesn't occur naturally as a base metal but is normally associated with mining processes, burning of fossil fuels and uses of cobalt containing phosphate fertilizers which are the major anthropogenic sources of environmental cobalt [8].

The central purpose of this investigation was to determine whether fish collected from two fish farms in Khartoum State were contaminated with levels of heavy metals, which could cause adverse effects on human health. First through quantifying concentrations of heavy metals namely Cobalt (Co), Manganese (Mn), Aluminum (Al) and Arsenic (As) in cultured fish, Oreochromis niloticus and *Clarias lazera.* Then perform a health risk assessment, following Environmental Protection Agency (EPA) methodology [9].

Materials and Methods

Fish handling and processing

A total number of 20 fish species were collected from Alshagara fish farm and Seleit Scheme fish farm. The specimens were placed immediately in poly-ethylene bags and then brought to the laboratory where they were immediately washed and dried. The species used were The Nile Tilapia *(Oreochromis niloticus*) and the Cat fish (*Clarias lazera*).

Before digestion, the fish were dissected. All of the tools used for dissecting flesh sampling were made of stainless steel to avoid contamination with metal residues. The gills, muscles and bones were taken out and homogenized once at a time. Each tissue was oven- dried to a constant weight at 60^0C [10]. The samples were ground into powder using a porcelain pestle and mortar .Prepared solutions were used for the Atomic Absorption Spectrometry analysis according to the method described by Pearson [11] to measure Co, Al, Mn and As concentrations in the gills, muscles and bones of the two selected fish species.

Risk Assessment Procedure

Intake Equation

The level of exposure resulting from the consumption of a particular chemical in fish muscles can be expressed by an estimation of daily intake levels according to National Academy of Sciences [12] in the following equation:

$$\text{Average Daily Dose (mg/kg-day)} = (C \times IR \times EF \times ED) / (BW \times AT)$$

Where: C = Total chemical concentration in fish tissue (mg/kg), IR = Ingestion rate of fish (kg/day), EF = Exposure frequency (days/year), ED = Exposure duration (years), BW = Body weight (kg), AT = Averaging time (days) (EDx365).

Estimation of Risk for Heavy Metals

The health risk is quantified by calculating Hazard Index (HI) according to the following equation:

$$\text{Hazard Index} = \text{ADD} / \text{Oral RfD}$$

Where: Hazard Index = Hazard Index of a health effect from intake of certain Chemical, ADD= Average daily dose (mg/kg-day). Oral RfD = Oral Reference dose of chemical (mg/kg-day).

The oral route is the route of exposure assumed in this study; therefore, oral RfD values from the EPA [9] database were used.

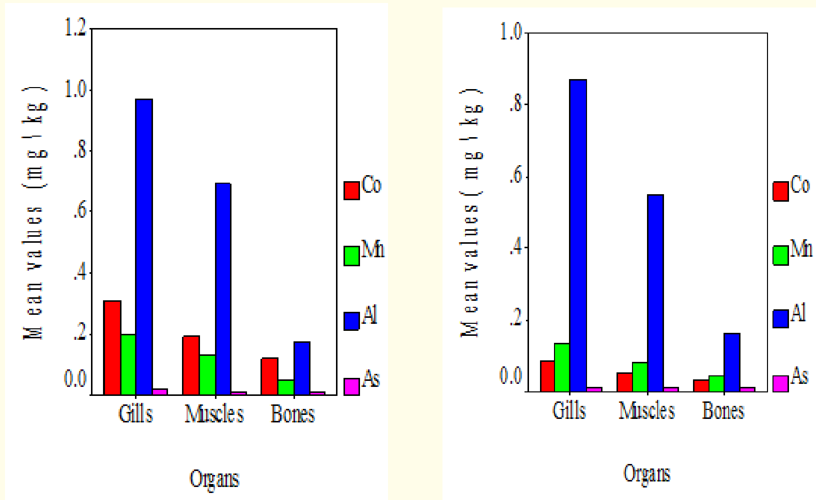
Statistical Analysis

Results of the heavy metal analyses were subjected to a one-way Analysis of variance (ANOVA) to test for significant differences ($p < 0.05$) using SPSS computer Software version 17. The values of Heavy metals were compared to the international standards.

Results

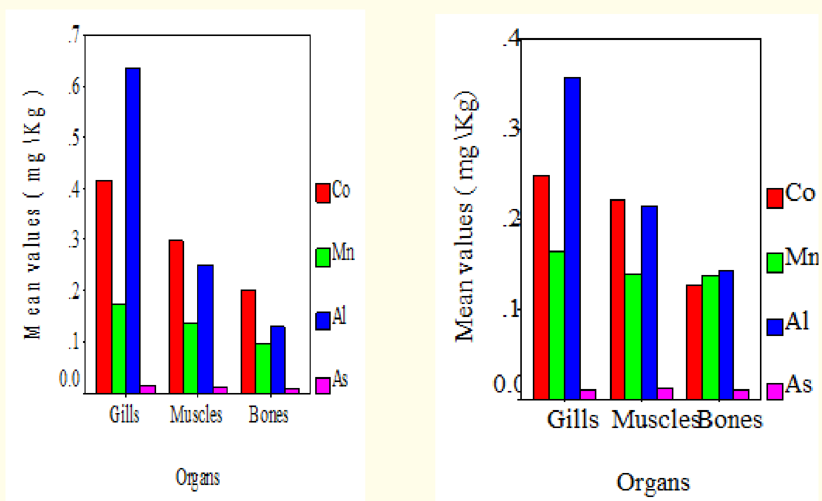
Concentration of heavy metals in the different organs in the two fish species

In fish collected from Alshagara, *O. niloticus* gave a significantly high ($p < 0.05$) concentration of Al reaching 0.967 mg/kg in the gills while the lowest concentration was in bones of the same fish collected from Seleit fish farm giving 0.131mg/kg. Results showed that As recorded lowest concentrations in both fish from the two farms. The concentrations of heavy metals in the different organs gave highest levels in gills followed by muscles and then bones in the two fish species as shown in figure1 (A-B) and figure 2 (A-B).



A B

Figure 1: *Mean values of different heavy metals in the different organs of (A) O. niloticus and (B) C. lazera from Alshagara fish farm.*



A B

Figure 2: *Mean values of different heavy metals in the different organs of (A) O. niloticus and (B) C. lazera from El-Seleit fish farm.*

Comparison of heavy metals accumulation in fish flesh to standard limits

Results revealed that fish flesh collected from Alshagara farm accumulated Mn and As at levels that exceed permissible levels recommended by FAO/WHO [1]. *O. niloticus* and *C. lazera* collected from Seleit scheme fish farm accumulated levels of Co, Mn ,As and Mn and As respectively that exceed permissible levels as shown in Tables (1 and 2).

Heavy metal	O. *niloticus*	C. *lazera*	FAO/WHO
Co	0.20 ± 0.015	0.05 ± 0.02	0.26
Mn	0.13 ± 0.01	0.08 ± 0.01	0.005
Al	0.70 ± 0.19	0.55 ± 0.14	1.0
As	0.01 ± 0.00	0.01 ± 0.00	0.003

Table 1: *Comparison of mean Heavy metal concentrations (mg/kg) in flesh of two cultured fish collected from Al shagara fish farm in Khartoum state and permissible limits in mg/kg.*

Heavy metal	O. *niloticus*	C. *lazera*	FAO/WHO
Co	0.3 ± 0.02	0.22 ± 0.06	0.26
Mn	0.14 ± 0.02	0.14 ± 0.04	0.005
Al	0.25 ± 0.06	0.21 ± 0.02	1.0
As	0.01 ± 0.00	0.01 ± 0.00	0.003

Table 2: *Comparison of mean Heavy metal concentrations (mg/kg) in flesh of two cultured fish collected from Seleit scheme fish farm in Khartoum state and permissible limits in mg/kg.*

Health Risk Assessment of Heavy Metals in Fish flesh

Average Daily Dose (ADD)

The calculated average daily doses for the four heavy metals detected are listed in Tables (3 and 4).

Heavy metal	O. *niloticus*	C. *lazera*
Co	0.0000137	0.0000137
Mn	0.00000916	0.00000916
Al	0.0000488	0.0000488
As	0.000000789	0.000000789

Table 3: *Calculated Average Daily Dose (mg/kg - day) Values of heavy metals consumption of O. niloticus and C. lazera collected from Alshagara fish farm.*

Heavy metal	O. *niloticus*	C. *lazera*
Co	0.0000210	0.0000157
Mn	0.00000979	0.00000977
Al	0.0000176	0.0000151
As	0.000000831	0.000000937

Table 4: *Calculated Average Daily Dose (mg/kg - day) Values of heavy metals consumption of O. niloticus, and C. lazera collected from Seleit scheme fish farm.*

Hazard Index calculations

Using the values of ADD calculated and oral reference dose [9] the hazard Index is calculated for the four studied heavy metals collected from the two fish farms in Khartoum state Results presented in Table (5) showed that heavy metals accumulated in fish collected from both fish farms gave a hazard index less than one thus indicating no health risk when consuming fish accumulating these levels.

Heavy metal	Oral RfD (mg/kg-day)	Hazard Index (HI)			
		O. nilticus (Alshagara)	C. lazera (Alshagara)	O. nilticus (Seleit)	C. lazera (Seleit)
Co	0.03	$4.57x10^{-4}$	$1.25x10^{-4}$	$7x10^{-4}$	$5.23x10^{-4}$
Mn	0.14	$6.54x10^{-5}$	$4.16x10^{-5}$	$6.99x10^{-5}$	$6.98x10^{-5}$
Al	0.0004	$1.2200x10^{-1}$	$1.2200x10^{-1}$	$4.4x10^{-2}$	$3.775x10^{-2}$
As	0.0003	$2.63x10^{-3}$	$2.93x1^{-4}$	$2.77x10^{-3}$	$3.12x10^{-3}$

Table 5: *Hazard Index (HI) Values for Co, Mn, Al and As at Mean Ingestion Rates in Flesh of fish from Al shagara and Seleit scheme fish farms.*

Discussion

In Sudan the Blue and White Niles host many towns, agricultural schemes and industrial projects which are situated at its banks. The Nile is therefore vulnerable to pollution risks. This study investigated four heavy metals namely Cobalt (Co), Aluminum (Al), Manganese (Mn) and Arsenic (As) in gills, muscles and bones of two cultured fish species; The Nile Tilapia *Oreochromis niloticus* and the cat fish *Clarias lazera*. The two fish species where collected from Alshagara fish farm situated along the White Nile and from Seleit scheme fish farm situated along the Blue Nile.

Results revealed that the highest accumulation was in gills of both species collected from the two farms . This finding agreed with that of Al-Weher [13] working with Cd, Cu and Zn. Fish are exposed to pollutants when taking in water in the process of respiration and osmoregulation. Therefore gills serve as the important route of heavy metal exposure from surrounding water [14].

Fish is an important source of protein for humans. It provides essential fatty acids as well as vitamins and minerals [15]. Fish muscle is the edible part of fish and frequently employed in assessing human health risks in relation to fish consumptions. The Hazard Index (HI) calculated in this study yield a number less than one for the four heavy metals detected from the two farms. This indicates that ingesting a daily mean concentrations detected in the fish flesh are not likely to cause adverse health effects. Zheng., *et al.* [16] showed the exposure to two or more pollutants may result in additive and/or interactive effects. Thus the total HI of heavy metals for individual fish can be treated as the arithmetical sum of the individual metal HRI i.e. Total HI (individual fish) = HI (Co) + HI (Mn) + HI (Al)+ HI (As). According to this theory it can be stated that the two species from both farms have HI less than one. Therefore it is not likely to experience any adverse health effects due to exposure to these fish species. In this study the levels of Mn and As were above international standard permissible levels although have an HI of less than one. Therefore it was concluded that there is an urge to establish suitable Sudanese standards according to Sudanese Demographic profile.

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