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*Original Paper*

# Determination of Cadmium and Lead in farmed fish tissues and feed in Khartoum State – Sudan


*Aied Berer Musa Ahmed [1,2], Hind A. Elnasri [1*]*

1) *University of Bahri, College of Veterinary Medicine , Khartoum , Sudan.*
2) *Ministry of Animal Resources – Khartoum - Sudan.*

*) *Corresponding Author: hindnasri2017@gmail.com*



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***Abstract*— Heavy metals are known for their toxic effects and lead to serious health problems. Fish is widely consumed, and the fish industry is rapidly growing. Heavy metals can accumulate in different parts of the fish from water, feed or sediment and can be further transferred to human consumers. The objective of the current study was to determine the concentrations of Cd and Pb in farmed fish tissues and fish feed. Fish tissues (head and fins, muscle and gills) in addition to feed samples were collected from two fish farms in Khartoum State. The levels of Cd and Pb were measured in the samples using Atomic Absorbance technique. Cd and Pb were detected in all samples examined, but their levels were below the acceptable limits set by FAO/WHO and EU. The muscle tissue was found to have the lowest concentration of both minerals (Cd 0.0092±0.001mg/g and Pb 0.203 ± 0.01 mg/g respectively) and the highest concentration was found in the fins (Cd 0.017± 0.001 and Pb 0.263 ± 0.011 mg/g respectively) .The levels in the feed were also found to be below the acceptable limits. Cd and Pb were detected in all samples studied, although the levels were below acceptable limits. Albeit that, the continuous and regular measurement is important to determine any potential sources that can increase their levels which further can affect the health of fish and humans.**



***Keywords*— Cadmium; Lead; fish tissue; fish feed; Nile tilapia; Sudan**


## I. Introduction

Fish is considered an important dietary material as it contains proteins, minerals, vitamins, high level of omega- 3-poly unsaturated fatty acids (namely eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)) which are essential for human health [1-3].

Heavy metals, unlike other organic pollutants, are non - biodegradable metallic elements with long-lasting toxic effects [4-5].Accumulation of these materials in the aquatic environment can lead to their transfer to the aquatic biota through different pathways [6] and can even affect species diversity and the entire ecosystem [7]. In addition, and through the food chain they can affect the human health.

Among the heavy metals that are known to negatively affect human health and lead to a variety of diseases are Lead (Pb) and Cadmium (Cd). Pb can affect the neurological system, kidneys, and blood circulation [8], while ingestion of Cd can rapidly cause nausea, vomiting, abdominal cramp, headache, diarrhea and shock [9].

Fish may be exposed to toxic metals from different sources including contaminated feed, sediment, and water [10-12]. Cd and Pb tend to precipitate under high water pH and hardness, and therefore, accumulate in higher amounts in the sediment fraction of an aquatic ecosystem. Thus fish can ingest the contaminated sediments accidentally in the feeding process [13].

The accumulation of heavy metals in fish tissues is strongly influenced by fish age, origin of the fish, species, pH and temperature of water, ecological conditions. Other factors include feeding habits, the tissue sampled, the season of harvest, especially for farmed fish, and the composition of the diet [14-15].

During fish raising, an important factor that determines the quality of fish flesh is the quality of fish feed [16]. Fish farmers mainly depend on formulated feed with fishmeal being a common ingredient in most fish feed formulations as an important source of proteins [17]. The raw material used for the production of this feed may be contaminated with various pollutants, including heavy metals [18].

The gills, skin, and digestive tract of fish species are possible sites for the absorption of waterborne xenobiotic [19-20].Usually these chemicals can be transported to different edible parts of fish such as bones, liver or muscle [21].

Currently, in Sudan, the fish industry is rapidly growing and the number of fish farms is also increasing. These farms are providing the local markets with an ample supply of fish instead of the previously available natural sources (the River Nile and the Red Sea). These farms depend to a large extent on ready- made formulations for the nursery and another for the growers. No much data is available about the level of Cd and Pb in the fish raised in these farms and feed.

This study aimed to determine the level of Cd and Pb in different tissues from fish raised on fish farms. The levels were also determined in fish feed. The levels were compared with the international permissible limits.

## II. Material and methods

### A. Study area

In the current study, two fish farms were selected, one located in West Omdurman locality and the other in North Khartoum, Bahri locality, Khartoum State, Sudan. The ponds are usually soil ponds, size approximately 0.50-1acre, depth 1.5m. They hold between 2000 to 2700 fish. Groundwater was used in both farms (Fig 1).

Fig. 1. Example of a fish pond in the country

### B. Sample collection

a. Fish samples were selected randomly after gaining weight of 252- 410 gm and were ready for marketing. The fish were divided into four parts: head and gills, muscle, fins and tail. The samples were stored in an ice box until they were transferred to the laboratory for analysis.

b. Feed samples were collected from each farm and stored in plastic bags.

All samples were analyzed at the Central Veterinary Research Laboratory, Soba, Khartoum.

### C. Laboratory analysis

a. Preparation of samples

Cd and Pb were measured using the atomic absorption technique. Briefly, 5 gms from the head and gills, fins and tail were placed in 20 ml HNO3 and left overnight. After filtration, 50 ml of distilled water was added. Regarding muscle tissues, five gms were burnt to ash, followed by addition of 10 ml HCL (50%) and 5ml HNO3 (33%). The mixture was incubated in a water bath for one hour. The solution was filtered, and the volume was completed to 100 ml with distilled water. The feed samples were prepared in a similar manner.

b. Measurement of Cd and Pb concentrations

Using standard solutions of both minerals, the concentration in the samples was measured using novAA350 Atomic Spectrophotometer, and the results were read using a special computer program

### D. Statistical analysis

The data were statistically analyzed using the statistical package, SPSS 20. One sample t- and nonparametric test were used. Results are expressed as Mean ±SD.

## III. Results and Discussion

The results of the current study showed that all samples collected contained Cd and Pb at different concentrations. The main fish type raised was the Nile tilapia (Oreochromis niloticus) (Fig 2). It is widely cultured since it can grow and reproduce in different environmental conditions and can tolerate various stress conditions resulting from handling[22].

Muscle is the most edible part of fish. The mean Cd concentration in the muscle was 0.0092± 0.001 mg/kg. This concentration was significantly lower ($p<0.00$) than the acceptable limits recommended by the FAO and WHO of 1mg/kg [23]. In all other tissues, the level of Cd was also below the acceptable limits set by FAO/WHO [23] and EU [24] (Fig.3, Appendix 1). Previous studies also reported Cd levels lower than the acceptable limits in different fish tissues [25-30]. In contrast, other studies have reported Cd level above the acceptable limits in different fish tissues [31-17].

Muscle tissue is not an active site for the Cd accumulation process and it preferentially accumulates in active metabolic organs, such as the kidney and liver, which are involved in organism detox mechanisms [32-12].

Fig. 2. Fish harvesting

When comparing Cd concentration between the different tissues, there was a significant difference ($p=0.000$) between the mean level of Cd in the muscle and other tissues where the muscle had the lowest concentration compared with the other tissues (Appendix 1). The highest Cd concentration was found in the fins (Fig.3).Similar results were reported previously [33]. This might be because fins are the last destination where the metal accumulates [33].

Previous studies reported higher levels of Cd in gills than in muscle [34-26- 27- 35]. In contrast, another study reported muscles having higher level of Cd than gills [25].Fish gills are known to accumulate excess Cd compared with other organs since gills are the first organs exposed to suspended sediment particles and are considered as an important interaction site with this metal [36-21]. Also, studies carried out in tilapia fish species reported that high levels of Cd in the gills might be due to the presence of high number of immature necrotic and apoptotic chloride cells, and apoptotic bodies in gills, which are sensitive to the high Cd uptake [37]. In addition, among the important factors that may affect the Cd level in tissues are the environment and sediment contamination. A previous study reported that the lowest Cd concentration was found in edible tissues of fish farmed in locations close to springs not polluted by sewage from urban or rural areas [38]. In Sudan, high levels of Cd and Pb were found in water and fish samples obtained from contaminated areas of the Nile River [39]. In addition, fish species that are likely to have more contact with contaminated sediments, can absorb metals from the sediment and store them within its tissues [40-41].

TABLE I. LEVELS OF CD AND PB IN DIFFERENT FISH TISSUES

| | | Mean | Std. Deviation | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound | | |
| Cd | muscle | 0.0092 | 0.00181353 | 0.007903 | 0.0104973 | 0.006 | 0.012 |
| | tail | 0.0117 | 0.00156702 | 0.010579 | 0.012821 | 0.009 | 0.013 |
| | head | 0.0127 | 0.00429599 | 0.009627 | 0.0157732 | 0.001 | 0.015 |
| | fin | 0.01522 | 0.0050767 | 0.011588 | 0.0188517 | 0.0012 | 0.018 |
| | Total | 0.012205 | 0.00403815 | 0.010914 | 0.0134965 | 0.001 | 0.018 |
| Pb | muscle | 0.2032 | 0.01387083 | 0.193277 | 0.2131226 | 0.186 | 0.23 |
| | tail | 0.2209 | 0.01497739 | 0.210186 | 0.2316142 | 0.2 | 0.242 |
| | head | 0.2424 | 0.00940685 | 0.235671 | 0.2491293 | 0.225 | 0.259 |
| | fin | 0.2662 | 0.01117338 | 0.258207 | 0.274193 | 0.249 | 0.284 |
| | Total | 0.233175 | 0.02675615 | 0.224618 | 0.241732 | 0.186 | 0.284 |

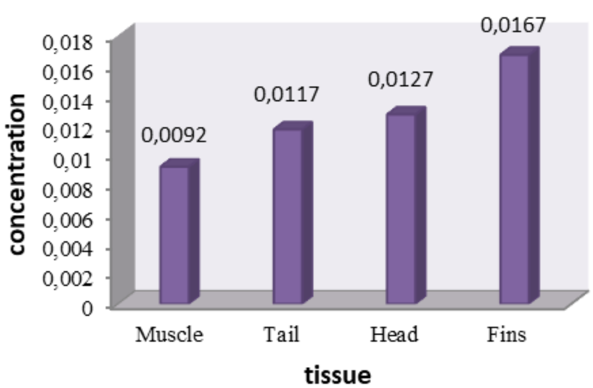


Fig. 3. Concentrations of Cd (mg/kg) in different fish **tissues**

Regarding Pb, the mean concentration of Pb in the muscle was 0.203 ± 0.014 mg/kg. This concentration was found to be significantly lower ($p<0.00$) than the acceptable limits of 2 mg/kg, set by EU [24].The concentration of Pb in other tissues was also below the acceptable limits (Fig.4).

Similar results have been reported [26- 28- 29] where the Pb level was found to be below acceptable limits. On the other hand, other studies reported Pb levels above the acceptable limits in fish tissues [17- 42-25- 30].

When comparing Pb concentrations between the different tissues, there was a significant difference ( $p=0.000$) between the mean levels of Pb in muscle and other tissues (being lowest in muscle) although the levels were below the acceptable limit (Fig.4), (Table 1). An earlier study reported that muscle had lower Pb level compared to gills [26], while another study reported muscles having higher levels of Pb than gills [25]. Similar to Cd, high concentration of Pb was found in the fins, which may be because fins are the last destination where the metal accumulate [33].

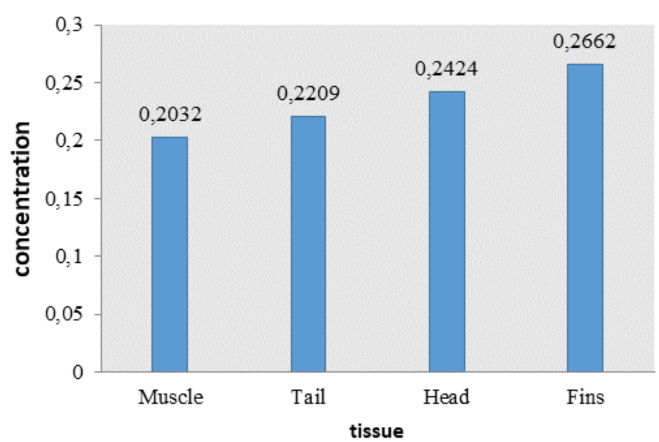


Fig. 4. Concentrations of Pb (mg/kg) in different fish tissues

The levels of Cd and Pb was also measured in fish feed. In Sudan, there are currently two main factories specialized in the preparation of fish feed. In addition, some farm owners prepare the feed within the farm using small machinery. The fish feed is mainly composed of fish meal, wheat, soya bean meal, salt, vitamins and minerals. The concentration of Cd in feed was 0.003±0.001 mg/kg which is significantly lower ($p<0.00$) than acceptable limits set by EU [24]. These results are similar to those of previous studies [27-25- 43-44 -29-45-46]. On the other hand Cd level was found to be above the acceptable limit [17].

The concentration of Pb in feed was 0.076±0.011 mg/kg, which is significantly lower ($p < 0.00$) than acceptable limit set by EU [24]. These results are in line with previous studies showing lower levels [25- 45] or even undetectable levels [47] and in contrast to other studies [43-44-17-28-46] showing Pb levels above the acceptable limit. The variations in heavy metal levels in fish feed are mainly affected by the different raw materials used in preparation of fish pellets [38]. If the trash fish already used contains high levels of metals, they may thus alter the levels of minerals in sediment and water. In contrast, the levels of Pb in the fish feeds, may not contribute to an increasing level in water or fish muscles, which may be because the pH of the water can limit the dissolution of metals and their absorption into the fish tissue [29] .

In the current study, no significant effect was found regarding the feed and tissues. A previous study, also reported non-significant variance between Pb in feed and fish [46] while another study showed that all metals from the feed positively correlated with the metals detected in the fish, but most of the estimated correlation was insignificant [16]. Thus heavy metals detected in fish tissues may not be acquired from ingestion of feed, but may result of other factors such anthropogenic activities in the area were fish are raised [47].

It is difficult to completely avoid contamination of animal feeds by toxic metals [17] and the increased level of minerals in feed is usually an indicator of the necessity to control their level in order to reduce both direct effects on animal health and humans.

## IV. CONCLUSION

Cd and Pb were detected in all tissues and feed examined. Fins had the highest level and the lowest concentration was detected in the muscles. Although their levels were below the acceptable limit, but the continuous monitoring is necessary to determine any potential sources of contamination that can elevate their concentration in fish. This can further affect the human health.


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