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Accumulation of Cadmium, Lead, and Mercury in Different Organs of Three Tuna Fish Species from Coastal Zone of Cote d'Ivoire

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Abstract – **Heavy metals are dangerous to aquatic organisms and it can be bioaccumulated in the food chain leading to diseases in humans. Cumulative effects of metals or chronic poisoning may occur as a result of long term expose even to low concentrations. The accumulation of heavy metals conditions depending upon the species, environmental conditions and inhibitory processes. Considering the human health risk due to the consumption of fish, the concentration of three heavy metals lead (Pb), cadmium (Cd), and mercury (Hg) are investigated in six organs (muscle, kidney, liver, gonads, brain, and gills) of tuna fish species (*Katsuwonus pelamis, Thunnus albacares, Thunnus obesus*) samples collected from the coast zone of Cote d'Ivoire. The results showed that the highest concentrations of the three metals (Cd, Pb, Hg) were observed in the gills and the liver. The organ less contaminated was the gonads. The mercury was accumulated preferentially in the gills, kidney, and muscle, while the cadmium and the lead were accumulated respectively in the liver and the brain. These metal concentrations were below the limits set by the world health organization (WHO).**

Keywords – **Tuna, Pollution, Heavy Metal, Organs, Bioaccumulation.**

I. Introduction

The aquatic environment is particularly sensitive to the toxic effects of contaminants since a considerable amount of the chemicals used in industry, urbanization and in agriculture enter marine and other aquatic ecosystems. Heavy metal contaminants have been reported in aquatic organisms [1]. These pollutants build up in the food chain and are responsible for adverse effects and death in the aquatic organisms. Heavy metals are stable and persist in environmental contaminants of aquatic environments and their organisms. According to WHO [2], metal occur in less than 1% of the earth's crust, with trace amounts generally found in the environment and when these concentrations exceed a stipulated limit, they may become toxic to the surrounding environment [2]. They occur in the environment both as a result of natural processes and as pollutants from human activity [1]. From an environmental point of view, coastal zones can be considered as the geographic space of interaction between terrestrial and marine species. The coastal zones are received a large amount of metal pollution from industrial activities, agricultural runoff, and other anthropic activities [3]. Heavy metals are dangerous to aquatic organisms and it can be bioaccumulated in the food chain leading to diseases in humans [3]. Cumulative effects of metals or chronic poisoning may occur as a result of long term expose even to low concentrations [1]. The accumulation of heavy metals conditions depending upon the species, environmental conditions and inhibitory processes. The rate of bioaccumulation of heavy metals in aquatic organisms depends on the ability of the organisms to metabolize the metals and the concentration of such metal in the water column.

Fish, as human food, are considered source of protein, polyunsaturated fatty acids particularly omega-3 fatty acids, Calcium, Zinc and Iron [3]. And it is considered one of the high nutrient sources for humans that contribute the lower the blood cholesterol and reduce the risk of stroke and heart diseases [4]. Among the aquatic fauna, fish is most susceptible to heavy metal contamination than any other aquatic fauna. Fish, as a bioindicator species, plays an increasingly important role in the monitoring of water pollution because it responds with great sensitivity to changes in the aquatic environment

Considering the human health risk due to the consumption of fish, the concentration of heavy metals (Pb, Cd and Hg) are investigated in organs of three species of tuna (*Katsuwonus pelamis, Thunnus albacares, Thunnus obesus*) collected from fish landing Port of Abidjan, Cote d'Ivoire.

II. Materials and Methods

2.1. Sample collection

The fish samples of Skipjack tuna (*Katsuwonus pelamis*), yellowfin tuna (*Thunnus albacares*) and bigeye tuna (*Thunnus obesus*) used for this study were collected from fish landing Port of Abidjan, Cote d'Ivoire. The fish samples transported to the laboratory in ice boxes and stored at -20ºC until future analysis.

2.2. Sample preparation

The fish samples were thoroughly washed with tap water and distilled water to remove any adhering contaminants and drained under folds of filter paper. The fish were subsequently dissected and muscle, liver, kidney, gills, gonads and brain) have been collected and stored at -20ºC until analysis.

2.3. Metal analysis

Three specimens from each species were used for the analysis. The tissues were oven dried at 70 to 73°C until constant weight was obtained. The specimens were then ground to fine powder and stored in desiccators in order to avoid moisture accumulation before digestion. The digestion procedure was carried out as described by AOAC [5]. Twenty milliliter (20 ml) of concentrated nitric acid (55%) and 10 ml of perchloric acid (70%) was added to approximately 1 g tissue (dry mass) in a 100 ml Erlenmeyer flask. The digestion was done on a hotplate (200 to 250°C) until the solutions were clear. The solutions were then filtered through an acid resistant 0.45 mm filter paper and made up to 50 ml each with distilled water. The samples were stored in clean glass bottles prior to the determination of the metal concentration using Atomic Absorption Spectrophotometer (ASS) as described by AOAC [6]. A standard sample, consisting of tuna homogenate (sample IAEA-350) from the International Atomic Energy Agency Marine Environment Laboratory, was prepared and used as a control in accordance with the afore-mentioned procedures with every set of samples, to ensure accuracy of data through comparison [6]. Analytical standards were prepared from Holpro stock solutions. Prior to use, all glassware were soaked in a 2% Contrad soap solution (Merck chemicals) for 24 h, rinsed in distilled water, acid-washed in 1 m HCL for another 24 h and rinsed again in distilled water. Each sample was analyzed in triple to ensure accuracy and precession for the analytical procedure

2.4. Statistical analysis

Heavy metal concentrations are expressed as µg/kg fresh weight. The values have been determined on average ± standard deviation. The average concentration of each metal in fish was calculated by the sum of averages in each organ studied. The variation of metal concentrations among organs was determined by analysis of variance (ANOVA). Comparisons of average levels of organs were carried out using the Duncan test when the differences are significant ($p < 0.05$). Analyses were made by software STATISTICA (version 7.1).

III. Results

The concentrations of heavy metals in Skipjack tuna *Katsuwonus pelamis* tissue are recorded in Table 1. Tissue metal concentrations vary depending on the metal and organs. Variance analysis indicated a significant difference ($p < 0.05$) at the level of each organ regardless of the metal concentrations. The mercury content is higher in the gills (474.81 ± 63.15 µg/kg fresh weight) followed by liver (266.12 ± 45.84 µg/kg fresh weight). The lowest mercury content was observed in gonads (58.32 ± 16.36 µg/kg fresh weight). The other organs have intermediate concentrations. As the lead, it is concentrated in the liver (531.47 ± 105.60 µg/kg wet weight) and brain (507.94 ± 119.56 µg/kg fresh weight) compared to other organs. The cadmium concentration was higher in the gills (49.06 ± 12.64 µg/kg fresh weight) but lower in the gonads (9.92 ± 2.38 µg/kg fresh weight). The overall order of heavy metal concentration in different organs of Skipjack tuna *Katsuwonus pelamis* was as follows:

- Hg: Gills > liver > kidney > muscle > brain > gonads
- Pb: Liver > brain > gills > kidney > gonads > muscle
- Cd: Gills > liver > kidney > brain > muscle > gonads

The concentrations of mercury, lead and cadmium measured in yellowfin tuna *Thunnus albacares* are presented in Table 2. Mercury concentrations were significantly higher ($p<0.05$) gill (440. 34 ± 105.24 µg/kg fresh weight) compared to other organs studied. The lowest concentration of mercury was observed in gonads (38.09 ± 10.03 µg/kg fresh weight). The lead was more concentrated in the liver, kidney and gills compared with muscle (112.28 ± 31.17 µg/kg wet weight) and gonads (81.31 ± 17.11 µg/kg fresh weight). The cadmium concentration was significantly higher in the liver (186.86 ± 53.30 µg/kg fresh weight) compared to concentrations measured in other organs. The concentration of cadmium in gills (50.55 ± 18.53 µg/kg wet weight) was intermediate. The overall order of heavy metal concentration in different organs of yellowfin tuna *Thunnus albacares* was as follows:

- Hg: Gills > kidney > muscle > brain > liver > gonads
- Pb: Brains > kidney > gills > liver > muscle > gonads
- Cd: Liver > gills > kidney > brain > muscle > gonads

Table 3 shows the mean values of mercury, lead and cadmium in the bigeye tuna *Thunnus obesus*. Mercury concentration in gills (475.93 ± 118.08 µg/kg fresh weight) was significantly higher ($p <0.05$) compared to other organs studied. The lowest concentration of mercury was observed in gonads (46.87 ± 20.55 µg/kg fresh weight). The lead was 2 or 3 times more concentrated in the brain (882.33 ± 196.42 µg/kg fresh weight) than in other organs. The lowest concentration of lead has been measured in muscle (156.60 ± 32.84 µg/kg fresh weight). The cadmium concentration is 20 times higher in the liver (276.13 ± 57.01 µg/kg fresh weight) compared to concentrations measured in other organs except in the gills where the concentration was intermediate (40.40 ± 17.43 µg/kg wet weight). The overall order of heavy metal concentration in different organs of bigeye tuna *Thunnus obesus* was as follows:

- Hg: Gills > muscle > kidney > liver > brain > gonads
- Pb: Brains > liver > gills > kidney > gonads > muscle
- Cd: Liver > gills > kidney > brain > muscle > gonads

Figure 1 shows the mean concentrations of mercury, lead and cadmium calculated in different fish species studied. The levels of mercury in the three species showed that the highest value was determined in *Katsuwonus pelamis* (233.57 ± 85.95 µg/kg fresh weight) compared to the other two species in which no significant differences were observed. The average lead concentration was significantly higher in *Thunnus obesus* (375.55 ± 35.77 µg/kg fresh weight) followed by *Katsuwonus pelamis* (332.58 ± 64.61 µg/kg fresh weight). The lowest average lead concentration was determined in *Thunnus albacares* (221.70 ± 87.48 µg/kg fresh weight). Regarding the cadmium concentration, the lowest value was determined in *Katsuwonus pelamis* (23.24 ± 12.89 µg/kg fresh weight) compared to that calculated in the other two species *Thunnus albacares* (48.44 ± 30.44 µg/kg wet weight) and *Thunnus obesus* (60.20 ± 35.50 µg/kg fresh weight). The order of accumulation of three heavy metals in three species of tuna landed in the fishing Port of Abidjan was as follows:

- Hg: *Katsuwonus pelamis* > *Thunnus obesus* > *Thunnus albacares*
- Pb: *Thunnus obesus* >*Katsuwonus pelamis* > *Thunnus albacares*

- Cd: *Thunnus obesus* >*Thunnus albacares* > *Katsuwonus pelamis*

Overall, the average concentration of lead in fish (309.94 ± 62.62 µg/kg wet weight) was higher followed by mercury (219.61 ± 70.61 µg/kg fresh weight). The cadmium concentration was the most low (43.96 ± 26.28 µg/kg fresh weight). Depending on different concentrations determined in studied organs, the order of bioaccumulation of heavy metals in tuna fish can be established as follows: Pb > Hg > Cd.

IV. Discussion

The different concentrations of heavy metals in the organs of three species of tuna landed in the fishing Port of Abidjan show a big organotropism. Bigeye tuna *Thunnus obesus* is the most contaminated by lead and cadmium. While cadmium is accumulated in the liver and gills, lead is more concentrated in the brain. Skipjack tuna *Katsuwonus pelamis* has the highest concentration of mercury. This metal is found mainly in the gills and liver in this species. On the other hand, yellowfin tuna *Thunnus albacares* is the less contaminated species of mercury and lead. Studied contaminants have been found in gills and kidney with regard to mercury in brain and kidney for which lead was higher. Bioaccumulation of heavy metal in the organism is dependent on many factors that can be classified into two groups. The first group concerns the abiotic factors which relate to its nature of chemical element, its concentration, its speciation, with or without a biological role [7]. The second group is the biotic factors appropriate to the organism and focuses on the species, its life history, sex, age, diet, including its composition and its metabolism [8]. Metal contaminants are then absorbed by active and passive processes. The combination of all these factors will determine the affinity or distribution, localization, and the bioaccumulation of metal contaminants in different tissues or organs including liver, kidney, and gills and to a lesser extent muscle [9].

Our results show the presence of metal trace in tissues in different proportions regardless of the species studied. Gonads and muscles are less contaminated by lead and cadmium regardless of the tuna species studied. However mercury concentrations are most important in muscle. They range from 180.53 ± 46.43 µg/kg fresh weight (*Thunnus albacares*) at 226.07 ± 64.86 µg/kg fresh weight (*Thunnus obesus*). Our data in the muscle are similar to those reported by Storelli *et al*. [8] in *Thunnus thynnus* in the Mediterranean Sea. On the other hand mercury is found preferentially in the gills in the three tuna species, while lead is mainly concentrated in the brain and liver. In *Katsuwonus pelamis*, this metal trace was mainly accumulated in the liver. On the other hand, in *Thunnus albacares* and *Thunnus obesus* the bioaccumulation of lead occurs primarily in the brain. Concerning cadmium, it founds in high concentrations in the liver and the gills depending on species studied. In, *Katsuwonus pelamis*, the most contaminated organ by cadmium is the gills. In contrast the cadmium was more concentrated in liver of *Thunnus albacares* and *Thunnus obesus*. The three heavy metals studied metal were found throughout the different organs of the three tuna species, but preferentially in the gills, liver, brain and kidney. The same observations were made by Hamza-Chaffai *et al*. [10]. According to these authors the heavy some metals have affinity for fatty tissues, showing by hepatic accumulation as well as in the brain except methylmercury which is more concentrated in the gills. Outside gills and gonads, the distribution of mercury seems be uniform in other organs. This observation does not corroborate the results of INERIS [11] who reported a high accumulation of mercury in the kidney compared to other organs.

Furthermore, our results indicate that gills and liver were more contaminated than the brain and much more than the kidney, muscle and gonads. This established order was well found by other authors who founded that this can be explained by their respective roles in the life of the fish [10].The gills are external organs which have direct contact with metals and effluents and playing an important role in respiration in fish. They are the main organs of absorption of the metal contaminants for aquatic species. According to Hamza-Chaffai *et al*. [10], the metallic charge of gills better reflects the relative importance of different metallic contaminants in the environment. The gills were used as an indicator for the monitoring of metal contaminants in the environment. In addition, the gills contain binding proteins called metallothioneins specifically refined metal contaminants [12], [13]. These authors suggest that ionized metals are primarily bioaccumulated through the gills of fish and conveyed through the circulatory system to the different organs.

According to our results the liver is the second organ which was more contaminated with a high concentration of cadmium in *Thunnus obesus* (276.13 ± 57.01 µg/kg wet weight) and *Thunnus albacares* (186.86 ± 53.30 µg/kg fresh weight). This fact has been observed by Canli & Atli [14] and Karadede *et al*. [15] who reported the affinity of cadmium for the liver, an organ for metabolism [14], [15]. Study of metal contaminants in liver can provide information on the contribution of diet (indirect way) in the exposition of fish. Also the capacity for storage and regulation of metal contaminants in the liver has been widely described in both *Thunnus albacares* and *Katsuwonus pelamis* tuna species studied [16] than in other species such as *Thunnus thynnus* [17], *Anguilla anguilla* [18], *Liza aurata* [19]. The liver is also an organ of the production of metallothionein detoxification [20], [21]. These proteins specialized in the chelation of the metals¸ play an important role in the homeostasis of the divalent metal ions [13], [22]. This is likely due to the very important physiological role of the liver in detoxification [23]. Furthermore our results of metal concentrations in the kidneys were similar to those reported by Jaffar & Ashraf [24] in *Thunnus thynnus* in the Arabian Sea.

V. Conclusion

Exposure of the three tuna species for metal contaminants (Cd, Hg, Pb) in their natural environment shows preferential accumulation of these metals according to the organs. Apart from the gills, external organs filtering water and retaining all of the metal contaminants, accumulation of metal contaminants in the internal organs (kidney, liver, muscle, brain and gonad) was preferentially according physicochemical forms of storage of metals. The cadmium was mainly concentrated in liver, while mercury was accumulated in muscle and kidney and lead showed primarily accumulation in the brain

In this study, the heavy metal concentrations were below the maximum levels recommended by regulatory agencies and, depending on daily intake by consumers, might represent no risk for human health. Finally, we recommended that a long-term continuous monitoring to check metals pollution, in order to control of metal in water and fish, control and assessment of the metal content in water of coastal zones area which are supplied by pollution from industrial activities, agricultural runoff, and other anthropic activities.

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Table 1: Heavy metal content in different organs of Skipjack tuna *Katsuwonus pelamis* (µg/kg wet weight, n = 96)

Métaux	Muscle	Liver	Kidney	Brain	Gonads	Gills
Hg	199.25±37.88[b]	266.12±45.84[c]	216.81±49.30[b]	186.12±64.42[b]	58.32±16.36[a]	474.81±63.15[d]
Pb	133.87±22.08[a]	531.47±105.60[c]	320.37±58.71[b]	507.94±119.56[c]	150.56±17.13[a]	351.25±40.22[b]
Cd	14.94±3.99[b]	28.19±11.02[c]	21.67±7.45[bc]	15.67±4.48[b]	9.92±2.38[a]	49.06±12.64[d]

The data are expressed on average ± standard deviation. Hg = mercury; Pb = lead; Cd = cadmium.
The different letters a, b, c, d on the same line indicate significant differences at $p < 0.05$

Table 2: Heavy metal content in different organs of yellowfin tuna *Thunnus albacares* (µg/kg wet weight, n = 264)

Métaux	Muscle	Liver	Kidney	Brain	Gonads	Gills
Hg	180.53±46.43[b]	169.41±39.06[b]	260.37±73.94[c]	174.77±57.99[b]	38.09±10.03[a]	440.34±105.24[d]
Pb	112.28±31.17[b]	277.38±58.04[c]	285.22±32.04[c]	295.99±90.03[c]	81.31±17.11[a]	278.05±45.80[c]
Cd	13.92±3.83[a]	186.86±53.30[c]	14.47±7.61[a]	14.41±5.81[a]	10.46±3.93[a]	50.55±18.53[b]

The data are expressed on average ± standard deviation. Hg = mercury; Pb = lead; Cd = cadmium.
The different letters a, b, c, d on the same line indicate significant differences at $p < 0.05$

Table 3: Heavy metal content in different organs of tuna bigeye tuna *Thunnus obesus* (µg/kg wet weight, n = 90)

Métaux	Muscle	Liver	Kidney	Brain	Gonads	Gills
Hg	226.07±64.86[c]	185.53±42.85[b]	201.13±48.88[bc]	162.53±31.08[b]	46.87±20.55[a]	475.93±118.08[d]
Pb	156.60±32.84[a]	341.13±53.14[c]	322.533±68.80[c]	882.33±196.42[d]	209.87±32.29[b]	340.87±51.73[c]
Cd	8.79±6.83[a]	276.13±57.01[c]	14.47±7.61[a]	12.06±6.02[a]	6.04±2.63[a]	40.40±17.43[b]

The data are expressed on average ± standard deviation. Hg = mercury; Pb = lead; Cd = cadmium.
The different letters a, b, c, d on the same line indicate significant differences at $p < 0.05$

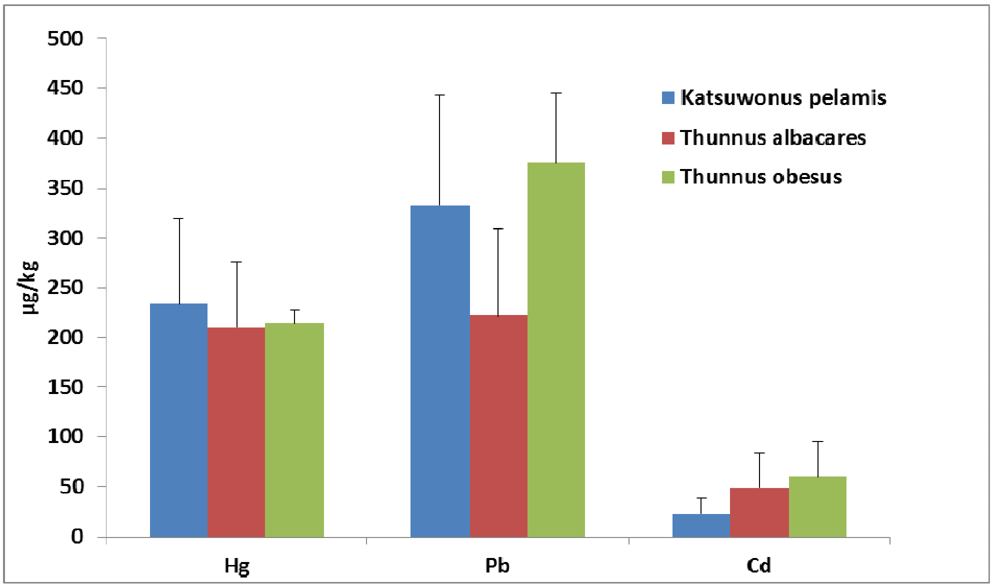

Fig.1. Average heavy metal content in the three species of tuna *Katsuwonus pelamis*, *Thunnus albacares* and *Thunnus obesus* collected from fish landing Port of Abidjan, Cote d'Ivoire (concentration in µg/kg wet weight)