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HEAVY METALS IN TUNA SPECIES MEAT AND POTENTIAL CONSUMER HEALTH RISK: A REVIEW

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Abstract. Marine fishes are one of the protein sources and they form a significant part of human diet around the world. In particular, tuna fisheries are considered as the largest and most specialized commercially important group of species among all commercial fishes. The preparing tuna methods such as cooking and canning might alter the level of heavy metals inside the meat. The heat that applied to the meat might be decreased the moisture content in tuna meat, thus give some effects to the heavy metal level. Other than that, the different composition and function of different parts of tuna can contribute to the various level of heavy metals analysed. The metal contamination in tuna species meat has put serious question to the safety level of fish intake to the community. It represent an abiding threat to human health as it has been linked to some adverse health effects such as mental retardation, kidney damage, and various types of cancer and even worse, death could occur. The following review articles presents the findings of the work carried out by the various researchers in the past on the heavy metal pollution in samples of Tuna species around the world.

1. Introduction

In the recent decades, world consumption of fish has been increased along with the rapid growing concern on their nutritional and therapeutic benefits [1]. Fish also being as an important protein sources for human health [2]. In our daily life, an adequate human diet should contain all the requirements for the energy and nutritive components. It is including essential polyunsaturated fatty acids, essential amino acids, mineral components, vitamins and fat [3,4]. According to Usydus et al. [4], resulting from the consistent content of essential polyunsaturated fatty acid like eicosapentaenoic and docosahexaenoic acid, fish known to



support good health to human. Other than that, fish contains different nutritional benefits mainly due to the high-quality protein contain in fish which provided 17 % of the total protein of animal origin and 6 % of the total protein intake by human, vitamin and essential elements [5]. Besides, they also have low in cholesterol, calories, sodium and saturated fat [6]. Similarly, tuna also provide healthy and affordable source of omega-3 fatty acids, protein, selenium and vitamin D to human diet.

Marine pollution can increase aquatic concentration of toxic metals and negatively affects the fish health [2]. Pollution from metallic element has become a serious issue due to their persistent, stable and nonbiodegradable nature [8]. Fish can accumulate toxic metals both through the water and food chain. They also can be considered as one of the most significant indicators of toxicity [9]. Muscle is main edible part of fish, forms the most preferred tool for assessment of public health risk associated with metal pollution in fish [10-13]. Metal bio-accumulation in fish can produce long-term impacts on biogeochemical cycling, where the accumulation of metal increased with the increasing of trophic level which then causing a significant risk to human health when consumed in amount exceeding the safe limit [14-15].

In present day, the metal pollution in fish has become a matter of great concern, due to their effects towards human health. It is generally assumed that the main pathway for metal exposure for human population is food consumption, particularly through fish and fish-derived products [18]. The risks to human are most notable when contaminated fishes are consumed beyond the allowed or recommended daily intake levels [6-7]. For example, ingestion has resulted in various adverse health impacts such as kidney failure, poor reproductive capacity, liver damage, skin and bladder cancer, and even death [17]. However, there are some essential metals such as Zn, Cu and Fe which are required for both aquatic organism and human body but the prolonged exposure to the excess limit could be toxic. On the contrary, there are some non-essential metals such as Cd, Pb and As that have no known potential benefits for a human being [18]. In this study, Tuna is the species that have the high concern on their heavy metal concentrations within the muscle and other major organs because they are among the top predator species. The common species of Tuna include Albacore tuna (*Thunnus alalunga*), Atlantic bluefin tuna (*Thunnus thynnus*), Skipjack tuna (*Katsuwonus pelamis*), Yellowfin tuna (*Thunnus albacares*) and Bigeye tuna (*Thunnus obesus*) (Figure 1).

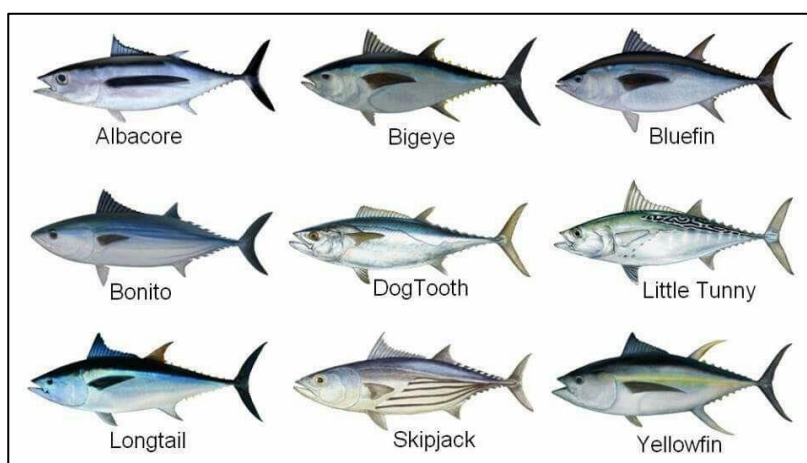


Figure 1. The common species of Tuna analysed for heavy metal content

Picture retrieve from <https://www.pinterest.com/chomjun/tuna/>

Metallic elements or heavy metals have special ecotoxicological importance because of their stability, persistence and toxicity [19]. They are known to bioaccumulated in organisms including plants and fish [6]. The presence of metallic elements in the environment is a consequence of both natural processes such as volcanic activity as well as anthropogenic activities including the fossil fuel combustion and agricultural sewage. In addition, human activities in and near coastal waters and around rivers draining into the world's estuaries and oceans have caused severe deterioration of water quality through heavy and trace metal contamination and pollution among many other issues [6]. Furthermore, the sediment of an aquatic system is not only an important reservoir of heavy metals but it is also an important source of heavy metals for aquatic organisms when the environmental conditions such as pH, redox potential and suspension are changed [20].

Although heavy metals are naturally occurring constituents in the environment, their concentration can be exacerbated due to rapid industrialization and urbanization, massive land use changes and associated enhanced terrestrial runoff [21] (Figure 2). According to Dhanakumar et al. [22], with the sharply rapid population growth and economic development, the increase in the discharge of wastes into aquatic environments has led to a significant increase in metal contamination. In many countries, significant alterations in industrial developments lead to an increased discharged of chemical effluents into the ecosystem, thus leading to the damage of the marine habitat [23]. Other than that, heavy metal pollution also caused by various sources, including industrial effluent discharged, sewage discharged, accidental chemical waste spills, and gasoline from fishing boats [24-26].

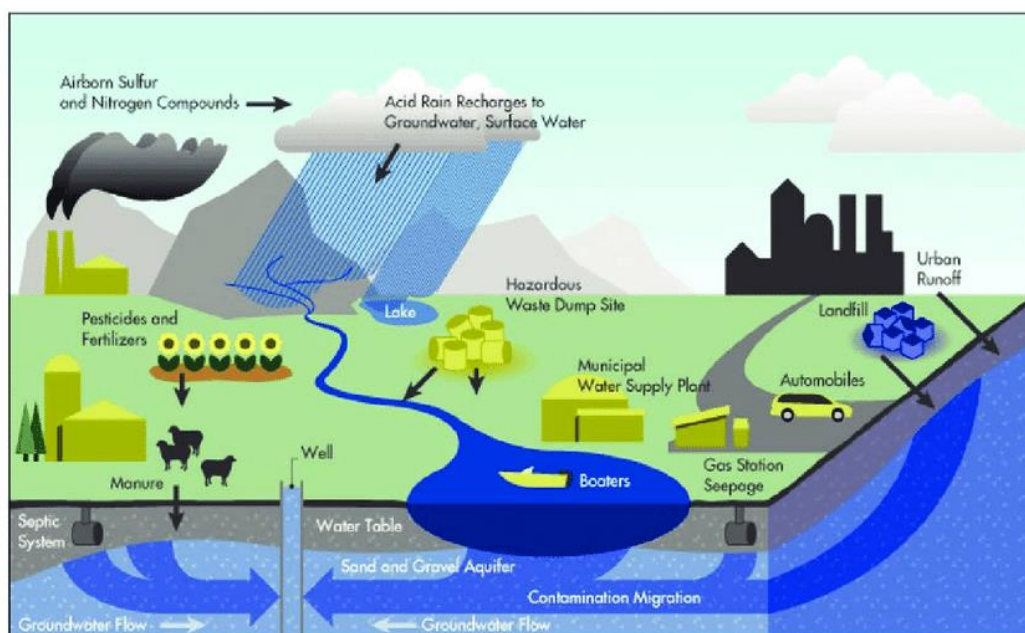


Figure 2. The anthropogenic sources of heavy metal pollution in aquatic environment.

(Picture courtesy of Pollution Probe: www.pollutionprobe.org/Publications/Primers.html)

2. Discussion

Extensive studies have been carried out by several researchers on heavy metal contamination in raw and cooked samples of Tuna family species including Bluefin tuna (*Thunnus thynnus*), Yellowfin tuna (*Thunnus albacares*) and Skipjack tuna (*Katsuwonus pelamis*). Rasmussen and Morrissey [28] studied the effect of canning on total mercury (tHg) content in troll-caught albacore tuna (*Thunnus alalunga*) harvested off the US Pacific Coast found that the concentration of mercury in raw samples ($0.17 \pm 0.4 \mu\text{g/g}$) has increase when compared to the canned sample ($0.21 \pm 0.05 \mu\text{g/g}$). Similarly, Vieira et al. [16] also found the mercury (Hg) content in the white and dark muscles of Skipjack tuna (*Katsuwonus pelamis*) has been increased in both white and dark muscle through the canning process. A small but significant difference in Hg concentration between white and dark muscle was observed either in the raw samples ($0.115 \pm 0.003 \mu\text{g/g}$ against $0.124 \pm 0.003 \mu\text{g/g}$) as also in the canned samples ($0.134 \pm 0.003 \mu\text{g/g}$ against $0.155 \pm 0.003 \mu\text{g/g}$). However, the mean concentration of Hg was significantly lower ($p < 0.05$) in the white muscle of Skipjack tuna ($0.122 \pm 0.004 \mu\text{g/g}$) when compared to the dark muscle ($0.140 \pm 0.004 \mu\text{g/g}$). These findings can be suggested that the mercury concentration in fish can be altered by various preparation methods including cooking and canning processes.

Similar result was reported by Afonso et al. [29] where the concentrations of mercury (Hg) and selenium (Se) were higher in grilled samples when compared to raw, boiled, canned with olive oil and canned with water. The higher concentrations of Se and Hg in grilled tuna was due to the loss of moisture when applying the dry heat. The loss of moisture does not occur in boiling or canning processes which applied wet heat to the tuna meats. Nevertheless, these claims can be contended by Schmidt et al. [30] on their study where they found that the concentrations of Hg in muscle of Yellowfin tuna (*Thunnus albacares*) were decreased after treated by some cooking methods such as boiling, frying, and roasting with application of salt and lemon juice. Therefore, they have assumed that the loss of Hg observed during the cooking processes probably due to Hg volatilization after its reduction to elemental mercury (Hg^0). Besides, tuna also commonly consumed as canned. Study by Mol [31] on the levels of selected heavy metals in canned tuna fish produced in Turkey found to be in the range of 20.2–8.7 $\mu\text{g/g}$ for Fe, 8.20–12.4 $\mu\text{g/g}$ for Zn, 0.48–0.58 $\mu\text{g/g}$ for Cu, 0.01–0.02 $\mu\text{g/g}$ for Cd, 0.02–0.13 $\mu\text{g/g}$ for Sn, 0.06–0.30 $\mu\text{g/g}$ for Hg and 0.09–0.45 $\mu\text{g/g}$ for Pb. The results showed that there was no risk with respect to the metal concentration towards human health except for some samples that may contain iron, lead and mercury above the legal limits set by FAO/WHO`

Meanwhile, Bosch et al. [32] have reported the average total mercury (tHg) concentration in Yellowfin tuna (*Thunnus albacares*) based on the muscle type, muscle position and fish size caught from the South Atlantic off the coast of South Africa was 0.77 µg/g. This value was below the maximum allowable limit of 1.00 µg/g for tHg intake set by FAO/WHO. However, the concentration of inorganic Hg (iHg) and total Hg (tHg) were found higher in dark muscle (0.159±0.075 µg/g, 0.873±0.286 µg/g) than white muscle (0.065±0.035 µg/g, 0.726±0.216 µg/g). The organic mercury (MethylHg and EthylHg) are considered as toxic and inorganic Hg (iHg) is considered non-toxic due to hardly absorbed into the living organism [29]. The different concentrations of mercury in this species might be due to the potential biases that existed when subsampling fish for measuring toxicity. The overall assessment of the concentration of Hg in dark and white muscle of Yellowfin tuna reveals that this variation could be caused by a dilution effect of the higher fat content of this portion of the carcass (white muscle). However, apart from the possible effect of fat content of muscle, the Hg variation observed in these types of muscle may be due to the differences in muscle function and therefore differing muscle fibre developments and composition [30]. On the other hand, Rueles-Inzunza et al. [34] have conducted the study on the distribution and biomagnification of cadmium (Cd) and lead (Pb) in muscle and stomach content in Yellowfin tuna (*Thunnus albacares*). This study found that the level of Cd and Pb were higher in stomach content compared to the muscle samples in both Skipjack and Yellowfin tuna. Stomach content were composed of crustaceans, fish and cephalopods and a corresponding transfer factors (TF) of Pb in Yellowfin tuna were above unity (1.46). This indicated that this element is biomagnified during transformation of the stomach contents into muscle. This claim can also be supported by similar research done by Gu et al. [35] on the heavy metals in fish tissues/ stomach contents in fish from western continental shelf of South China Sea. They found that the concentration of some heavy metals such as Cd, Pb, Cr, Ni, Cu and Zn were higher in stomach content of Bigeye tuna (*Thunnus obesus*) compared to various tissues (muscle, backbone and gills). Thus, suggested that the heavy metal concentration accumulated in this species were mainly due to their diet.

Chouvelon et al. [36] measured seven selected trace metals (nickel, copper, zinc, cadmium, mercury, and lead) in muscle of Albacore tuna (*Thunnus alalunga*) collected over two seasons/years in the Western Indian Ocean (WIO: Reunion Island and Seychelles) and in the South-Eastern Atlantic Ocean (SEAO: South Africa). According to their study, they found that the mean concentration of Ni, Cu, Zn and Cd were higher in samples from South Africa while samples from Seychelles was the lowest one. In all analyses performed, they suggested that the significance of geographic origin for explaining variability in metal concentrations was effectively the highest, and notable once the effect of size had been taken into account. This indicated that, geographic differences in tuna trace metal concentrations are therefore most likely due to the differences in the different types of prey and food web exploited. On the other hand, Nicklisch et al. [37] reported the variety level of mercury contents in Yellowfin tuna (*Thunnus albacares*) are associated with the capture location. Their study on mercury describes its presence and variation in different 12 different locations worldwide. The 12 locations were including the North East Pacific Ocean (NEPO), Gulf of Mexico (GOM), South East Pacific Ocean (SEPO), Northwest Atlantic (NWAPO), Northeast Atlantic Ocean (NEAO), South East Atlantic Ocean (SEAO), Indian Ocean (IO), South China Sea (SCS), North China Sea (NCS), Northwest Pacific Ocean (NWPO), Southwest Pacific Ocean (SWPO) and the North Pacific Ocean (NPO). This study reveals that the methylmercury levels showed no correlation with the lipid content in the muscle tissue. Indeed, the fish with the highest methylmercury concentration of 0.821 µg/g wet weight from the NPO has a low lipid content of less than 0.6 wt%. In contrast, a strong effect has been observed when examining the impact of capture location on mean methylmercury levels. The highest concentration of MeHg was found in fish from NPO and the lowest in fish from NWPO. Notably, 10 out of these 20 least polluted fish were all caught in the

NWPO, with the lowest MeHg concentration of 0.032 µg/g wet weight. According to this study, there was suggested that the dynamic sources of both natural and anthropogenic sources of Hg contribute to the Hg in the environment. The findings reveal that two of the most contaminated sites were relatively distant from human terrestrial inputs, including the NPO and SWPO. However, these sites could be downwind of atmospheric sources of mercury originating in Asia.

3. Conclusion

This review article summarizes the metal pollution in Tuna species meat worldwide. Several studies of heavy metal pollution in Tuna species including the Bigeye tuna, Albacore tuna, Yellowfin tuna, Skipjack tuna as well as the canned tuna. Preparing methods such as cooking and canning has increased the concentration of heavy metals inside the tuna meats due to the loss of moisture. On the other hand, the accumulation of heavy metals might be various due to the differences in muscle function and therefore differing the muscle fibre developments and composition. Some studies revealed that the levels of selected heavy metals were above the maximum allowable intake and thus might give the adverse impact to human health. Overall, the accumulation of heavy metals in tuna meat are depending on several factors such as the composition of muscle, the preparing methods as well as the location where the tuna have been caught.

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