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Heavy metal concentrations in *Liza aurata* (Risso, 1810) captured from the Kerkennah Islands (Gulf of Gabes) and associated health risks

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ABSTRACT

Objective: To determine the concentration of heavy metals (Cd, Cu, Fe, Ni, Pb and Zn) in the liver, gills and muscle of *Liza aurata* (*L. aurata)* collected from the Kerkennah Islands. The target hazard quotient was also used as an indicator of human health risks associated with fish consumption.
Methods: The sample was collected from Kerkennah Islands (Gulf of Gabes, Tunisia). Heavy metals in *L. aurata* tissues (gills, liver and muscle) were analysed with an atomic absorption spectrometer (PerkinElmer).
Results: As expected, muscle always possessed the lowest concentrations of all metals. The maximum concentrations of Cd (0.52 mg/kg wet weight), Cu (5.43 mg/kg wet weight), Fe (115.27mg/kg wet weight) and Zn (112.20 mg/kg wet weight) were measured in the liver, while the highest Ni (1.54 mg/kg wet weight) and Pb (1.43 mg/kg wet weight) were recorded in gills. The target hazard quotient through consumption of fish and calculated by adding the inividual target hazard quotient was below 1, indicating that there was no significant potential health risk associated with consumption of *L. aurata*.
Conclusions: *L. aurata* from the Kerkennah Islands may be suitable for human consumption.

1. Introduction

The Gulf of Gabes (between 33° N and 35° N) extends from Ras Kapoudia at the 35° N parallel level to Tunisian-Libyan border and shelters various islands (Kerkennah and Djerba) and lagoons (Bougrara and El Bibane). Despite to the high anthropogenic and industrial activities set up in this gulf, it contributes to 65% of the national fish production in Tunisia[1,2].

Liza aurata (*L. aurata*) (Risso, 1810) is an important target species for Tunisian fisheries and particularly for those in the Gulf of Gabes[3]. This is a cosmopolitan species inhabiting all tropical and temperate seas. It is found inshore and enter the lagoons and estuaries. It is able to utilize the food distributed from the thin water film to bottom mud, either by direct grazing or using plant-detritus food chains as an energy source.

Like essential metals, non-essential ones are also absorbed and accumulated in fish tissues[4]. Therefore, the content of toxic heavy metals in fish can counteract their beneficial effects[5]. Thus, heavy metals pollution in fish becomes an internationally important concern, not only because of the threat to fish, but also due to the health risks associated with fish consumption. Given that, the present study was undertaken to determine the concentration of heavy metals (Cd, Cu, Fe, Ni, Pb and Zn) in different tissues of *L. aurata* collected from the Kerkennah Islands. The target hazard quotient (THQ) was also used as an indicator of human health risks associated with fish consumption.

2. Materials and methods

2.1. Study site

The Kerkennah Islands are located in the northeast of the Gulf of Gabes (Figure 1) and are influenced by regional water circulation[6]. They exhibit shallow coastal waters with an average ranging from 0 to 5 m[7].

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All experimental procedures involving animals were conducted in accordance to the handling of the animals and approved by Tunisian Ethical Committee of the University of Sfax (Tunisia).

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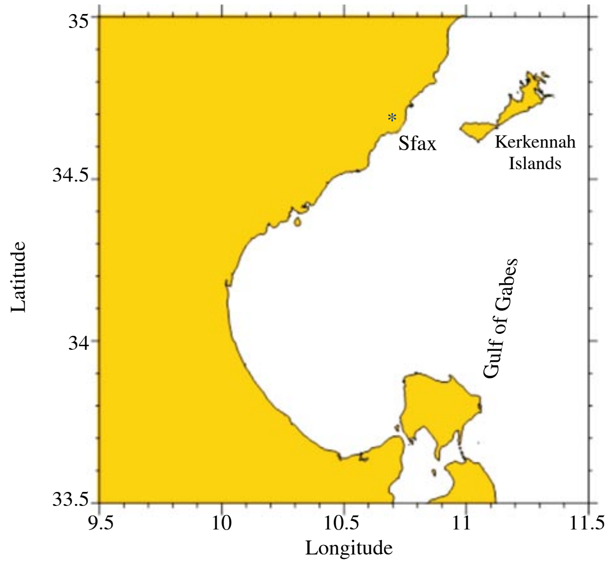

Figure 1. Location map of the study area, Kerkennah Islands.

2.2. Fish sampling

L. aurata was purchased from fishing boats in Kerkennah Islands during February 2015. This species is economically important and widely consumed in the region. Collected specimen was wrapped in polyethylene plastic, put into an industrial cold container, and brought to the university laboratory where they were weighted, measured the total length and kept frozen at –20 °C until dissection [fish size (284.10 ± 0.29) mm; fish weight (65.80 ± 1.42; n = 10)]. For bioaccumulation analysis, the gills, liver and muscle were prepared for metal analysis. One gram of each sample was digested with 6 mL HNO_3 (65%). Digestion was performed on a hot plate at 103 °C, for about 6 h until a clear solution was obtained. All experimental procedures involving animals were conducted in accordance to the handling of the animals and approved by Tunisian Ethical Committee of the University of Sfax (Tunisia).

2.3. Heavy metals analysis

The concentrations of Cd, Cu, Fe, Ni, Pb and Zn in *L. aurata* tissues were determined with an atomic absorption spectrometer (PerkinElmer). Metals concentrations were expressed as mg/kg wet weight.

2.4. Health risk from fish consumption

The THQ, a ratio between the exposure and reference doses (a reference dose or R_{fd}) (1×10^{-3}, 4×10^{-2}, 11×10^{-3}, 4×10^{-3} and 3×10^{-1} for Cd, Cu, Pb, Ni and Zn, respectively), was used to expess the risk of non-carcinogenic effects. The methodology for estimating THQ was described in the United States EPA Region III risk-based concentration table[8].

THQ values may be estimated by using the following equation[9]:

$$\text{THQ} = \frac{E_f \times E_d \times F_{ir} \times C}{R_{fd} \times W_{ab} \times T_a} \times 10^{-3}$$

where E_f is exposure frequency (365 days/year), E_d is exposure duration (70 years, average lifetime), F_{ir} is food ingestion rate (g/day), C is heavy metals concentration in fish (mg/g), R_{fd} is oral reference dose (mg/kg per day), W_{ab} is average adult body weight (65 kg) and T_a is averaging exposure time for non-carcinogens (365 days/year × number of exposure years, assuming 70 years). It has been reported that exposure to two or more pollutants may result in additive and/or interactive effects[10]. The daily intake of fish in Tunisia is 39 kg/person per year (INS, 2010 in Dhraief *et al.*[11]). The food ingestion rate was estimated at 50 g/day, since this species is among the most edible species in the region. A value of THQ < 1 indicates no obvious risk. If the THQ is equal to or higher than 1, then there is a concerning health risks.

The total THQ was treated as the arithmetic sum of the individual metal THQ values, derived by the method of Chien *et al.*[12]:

Total THQ (TTHQ) = THQ (toxicant 1) + THQ (toxicant 2) + …… + THQ (toxicant n).

It was further assumed that cooking has no effect on the toxicity of heavy metals in seafood[12,13].

2.5. Data analysis

The results were expressed as mean ± SD. Data were statistically analyzed by using Tukey's multiple range test to determine in means as indicated by different case letters in the descending order, which was a, b and c at $P < 0.05$. The analyses were performed by using the software statistical package for the social sciences (SPSS, Ver. 20).

3. Results

3.1. Heavy metal concentrations in fish tissues

The variation of metal (Cd, Cu, Fe, Ni, Pb and Zn) accumulation in mullet tissues (gills, liver and muscle) was presented in Table 1. Nickel concentration was not detected in muscle. The pattern of metal accumulation in mullet tissues was in decreasing order: for Cd, Cu, Fe and Zn: liver > gills > muscle, and for Ni and Pb: gills > liver > muscle.

Thus, the metals accumulation was higher in liver and gills than in muscle.

Table 1
Metal concentrations in tissues of *L. aurata* (mg/kg wet weight).

Metal	Gills	Liver	Muscle	Permissible limits
Cd	0.25 ± 0.03^{b}	0.52 ± 0.01^{c}	0.09 ± 0.02^{a}	1.0^{A}, 0.5^{B}
Cu	0.90 ± 0.00^{b}	5.43 ± 0.12^{c}	0.12 ± 0.01^{a}	$30.0^{A,B}$
Fe	51.32 ± 0.05^{b}	115.27 ± 1.34^{c}	15.54 ± 0.04^{a}	100.0^{A}
Ni	1.54 ± 0.12^{b}	0.68 ± 0.01^{a}	nd	$0.5–1.0^{A}$
Pb	1.43 ± 0.05^{c}	0.55 ± 0.01^{b}	0.24 ± 0.02^{a}	2.0^{A}, 0.5^{B}
Zn	104.10 ± 0.03^{b}	112.20 ± 0.05^{c}	35.32 ± 0.11^{a}	100.0^{A}, 40.0^{B}

Data were expressed as mean values ± SD. nd: Not detected. Different letters indicate significant differences between tissues $^{a} < ^{b} < ^{c}$, ($P < 0.05$). ^{A}: World Human Organization (WHO); ^{B}: Food and Agriculture Organization (FAO)/WHO.

3.2. Health risk assessment

Table 2 presents the estimated THQ for individual metals and the total THQ from consumprion of *L. aurata* by, the general population in Kerkennah Islands. It was shown that there were no THQ values over one through the fish consumption, indicating that health risks associated with the intake of individual metals was insignificant.

Table 2
Estimated THQ for individual metals and total THQ from consumption of *L. aurata*.

	Cd	Cu	Ni	Pb	Zn	Total THQ
THQ	0.070	0.002	0.000	0.050	0.170	0.290

The estimated THQ for individual metal was decreased in following sequence: Zn > Cd > Pb > Cu > Ni. Zn was the major risk contributor accounted by 58% of the total THQ followed by Cd, Pb and Cu with 24%, 17% and 1% of total THQ, respectively. The total THQ for the general population at the studied site was below the classification of no risk level (total THQ < 1), recommended by US Environmental Protection Agency[8] (Table 2).

4. Discussion

Cd and Pb are non-essential metals. Cd is highly toxic and ecotoxic[14]. They may be accumulated in human body and can be very harmful to human health[15,16]. The highest amount of Cd [(0.52 ± 0.01) mg/kg wet weight] and Pb [(1.43 ± 0.05) mg/kg wet weight] were recorded in liver and gills respectively. The concentrations of Cd (liver) and Pb (gills) are higher than the permitted level 0.5 mg/kg wet weight set by FAO/WHO[17].

Cu, Fe and Zn are essential metals, but they produce adverse hearth effects with excessive intake[18-20]. Cu is a key constituent required as a catalytic cofactor in metabolic enzymes[21]. Fe is a constituent of myoglobin, hemoglobin and of several enzymes[22]. Zn is involved in most metabolic pathways in humans[23]. The liver is the target organ of Cu, Fe and Zn with 5.43, 115.27 and 112.20 mg/kg wet weight respectively. The Fe and Zn concentrations in liver exceed the maximum allowable limits, 100 mg/kg wet weight set by FAO/WHO[17] while Cu concentrations are below the maximum allowable limits, 30 mg/kg wet weight set by FAO/WHO and WHO[17,24]. Nickel is an essential element, but it can be very harmful to human health when consumed in high amount[25,26]. The highest Ni concentration [(1.54 ± 0.12) mg/kg wet weight] was found in gills. This concentration exceeds the maximum allowable limits 0.5–1.0 mg/kg wet weight[17].

Distribution of pollutants among the various organs within an organism is heterogeneous, but rather they accumulate in specific target organs[27].

Gills are the main place for gas exchange in fish[28] and are given the short distance between blood and surrounding seawater. Heavy metals may rapidly be taken up from the passing water[29]. Thus, The marked concentrations of metals in the gills could due to accumulative capacity of this organ in depuration and absorption of uptaken heavy metals[30].

The liver is highly active in the uptake and storage of heavy metals[31]. Fish respond to metal that were exposured by producing metallothioneins[32]. Liver is targeted in metals accumulation due to its role as metabolic organ[33]. The high amounts of Zn and Cu in liver are likely linked to a natural binding protein such as metallothioneins[28], acting as an essential metal store (Zn and Cu) to fulfill enzymatic and other metabolic demands[34]. Also, Fe tends to be accumulated in liver due to its physiological role in blood cells and hemoglobin synthesis[35]. On the other hand, as essential metals, non-essential ones, such as Cd, showed high levels in liver. High concentrations of Cd could be relate to the ability of this element to displace the normally metallothionein-associated essential metals in liver[34]. Similar results of high Cd, Cu, Fe and Zn concentrated in liver tissue were reported in many field studies[5,33,36].

It is well known that muscle is not an active tissue for metal biotransformtion and accumulation[37]. But in polluted site, the metal concentrations in fish muscle may exceed the permissible limits for human consumption, so it is important to compare these to known safe levels, since the muscle is the most important part consumed by human population[4,38,39]. While comparing with the others studies carried out in the Mediterranean Sea, the concentrations of Cd, Cu, Fe, Ni, Pb and Zn in the muscle of *L. aurata* are lower than those found by Ketata Khitouni, *et al*.[40] (Gabes Gulf area), Ersoya and Celik[41](Iskenderun Bay).

The risk assessment is one of the fatest methods, based on the THQs, which is needed to evaluate the hazard impacts on human health from fish consumption and to determine levels of treatment which tend to solve the environmental problem that occurs in daily life[8,42]. When the THQ exceeds one of the seafoods that has health risk concern[43]. Our results revealed that the THQ of individual and total metals would not pose potential health risk. Thus, the population were not experiencing any health effects.

The levels of all studied metals in *L. aurata* muscle were found to be below the established limits for these metals according to WHO/FAO and WHO[17,24]. Cd, Cu, Fe and Zn were preferentially accumulated in the liver while Pb and Ni were higher in the gills. The THQ values for individual metals showed that there was no health risk for human due to the intake of inividual heavy metals in *L. aurata* from Kerkennah Islands. The total THQ on humans, due to the combined effect of all metals considered in the present study, was also less than one, which signifies that there is no health risk from *L. aurata* consumption.

Conflict of interest statement

We declare that we have no conflict of interest.

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