Asian Journal of Chemistry; Vol. 27, No. 12 (2015), 4411-4416

ASIAN JOURNAL OF CHEMISTRY

http://dx.doi.org/10.14233/ajchem.2015.19148

Heavy Metals Concentrations in Fish from Red Sea and Arabian Gulf: Health Benefits and Risk Assessments due to their Consumption

K.T. KAMAL*, K. LOTFI, K.D. OMAR, R.E. MOHAMED, K.M. ABUELIZ and H. NASSIR

Department of Chemistry, College of Science, AI Imam Mohammad Ibn Saud Islamic University, P.O. Box: 5701, Riyadh, Kingdom of Saudi Arabia

*Corresponding author: Fax: +966 112586678; Tel: +966 551799861; E-mail: kamaltha99@rediffmail.com

Received: 3 March 2015; *Accepted*: 15 May 2015; *Published online*: 29 August 2015; AJC-17482

Seafood contains heavy metals essential to human health and also contaminants that can induce toxicity into consumers. In order to evaluate the benefits and risks to human health, this study targeted the analysis of Cd, Cr, Cu, Fe, Mn, Ni, Zn, Al and Se as essential elements and Cd, Pb and As as toxic elements in the muscle tissues of two popular types of fish: Areolate grouper (*Epinephelus areolatus*, local name; Hamoor) and Coral Trout (*Plectropomus maculatus*, local name; Najil) from the Red Sea and Arabian Gulf, Saudi Arabia. The metals under investigation were determined using inductively couples plasma emission spectroscopy after wet digestion. The concentration of essential elements were found to decrease in the order: Zn > Fe > Al > Cu > Se > Ni > Cr > Mn while the toxic elements in the order: As > Pb > Cd. The study revealed that *P. maculatus* from both study areas bioaccumulate more Cd, Cr, Fe, Mn, Ni, Pb and Se compared to *E. areolatus* while both species from the Red Sea accumulate more As. Arsenic, Cd and Pb target hazard quotient (THQ) values were less than 1.0 indicating a safe consumption of this types of fish. Moreover the cancer risk factor for As was more than the 10^{-5} threshold permitted life risk for the different exposure frequencies. The number of meals per week a frequent monitoring of metals content of fish to safeguard consumers.

Keywords: Heavy metals, Fish, Total hazard quotient, Red sea, Arabian Gulf.

INTRODUCTION

The world consumption of seafood has considerably increased in recent years due to its great health benefits in prevention of diseases such as cardiovascular problems and brain hemorrhage[1]. Fish and other seafood products are considered a valuable source of high quality proteins, omega-3 unsaturated fatty acids, selenium and vitamins[2-5].

Metals are required for their biological roles in life processes and hence their presence in trace amounts is essential[6]. For instance, iron is a mineral essential for life. It is necessary for the production of hemoglobin, myoglobin and certain enzymes. On the other hand Fe deficiency can cause weakness, inability to concentrate and susceptibility to infection. According to the World Health Organization, iron deficiency anemia is one of the most common nutrient deficiencies in the world[7]. Manganese helps to prevent cardiac arrest, heart attack and stroke. At high concentrations it is quite toxic and can induce psychologic and neurologic disorder[8]. Zinc is an essential trace metal for both animals and humans. Still at concentrations up to 40 mg/kg, Zn may induce toxicity, characterized by symptoms of irritability, muscular stiffness and pain, loss of appetite and nausea[9]. Consequently FAO has set a maximum guideline of 30 mg/kg of Zn for safe human consumption[10]. Copper is an essential part of several enzymes and it is necessary for the synthesis of haemoglobin[11]. Thus essential elements are toxic if present in excess to permitted levels[12]. Excess Fe and Mn can deposit oxides in Parkinson disease[13]. Liver damage can be caused by excess Cu and reduction in immune function by excess Zn[14]. At higher concentration Ni is toxic and can increase red blood cells number and reduce lung performance[15]. On the other hand Pb and Cd are toxic even at a very low concentration and no biological significance is known for them. Lead can cause renal tumor and high blood pressure for adults and reduce cognitive development for infants and children[16]. Aluminum toxicity is related to neurotoxicity and neurodegenerative disease development[17]. Cadmium exposure is detrimental in hypertension and may lead to upnormal behaviour and decreased IQ of children and adults[18]. Arsenic toxicity is a function of its oxidation state, where As(III) is toxic compared to As(IV). The toxic inorganic As represents only 3 % of the total As[19,20] whereas more than 90 % of As is in the form of arsenobetaine which gets methylated and excreted through urine[21]. The high intake of inorganic As is associated with increased risk of cancer[21-24].

Fish can accumulate metals *e.g.* Cr[25], Cu, Zn, Ni[26], Pb, Cd[27,28], As[29], Fe, Mn and Se[30] in their tissues. Thus fish can be considered a real indicator of environment toxic substances bioaccumulation and their analysis can give an estimation of contaminant exposure risk to consumers[31].

As a result of natural emissions and anthropogenic activities[32-34] toxic heavy metals find their way to aquatic ecosystems. Consequently these pollutants are assimilated and bioaccumulated in the bodies of aquatic organisms and ultimately into human body through food chains[35] leading to hazardous effects upon health. It is apparent that whenever seafood consumption is studied, nutritional-toxicological balance has to be considered. Along with the benefits there are also concerns about consumer exposure to toxic substances accumulated in fish edible tissues[3,11,16,36].

The probability risk assessment method to estimate the impact of hazardous pollutants upon human health has been adopted by many researchers[37-40].

The estimated daily intake per meal size of fish (ED_{mL}) for each element was calculated[41,42] according to the equation:

$$ED_{mL} = Ms \times C \qquad (1)$$

where Ms is the meal size (g) and C is the metal concentration (μg/g).

Target hazard quotient (THQ) is the parameter usually considered by many authors as a valid indicator to the extent of exposure of a population to an adverse health risks[43,44]. Target hazard quotient was calculated[45] using the following equation:

$$THQ = \frac{EF_r \times ED_{total} \times FIR \times C_f \times C_m}{R_{fd0} \times BW_a \times AT_n} \qquad (2)$$

where EF_r is the exposure frequency (365.25 days/year), ED_{total} is the exposure duration (years) or average lifetime, FIR is the food (fish) ingestion rate (g/person/day), C_f is the conversion factor from wet to dry weight (0.208), C_m is the heavy metal concentration in fish edible part (μg/g), R_{fd0} is the oral reference dose (mg/kg/day), BW_a is the body weight (kg) and AT_n is the averaging exposure time for non-carcinogens (365 days/year x number of exposure years)[8]. The level of exposure is considered less than the reference dose if target hazard quotient value is less than 1.0 and hence no obvious risk is encountered. If target hazard quotient > 1.0 there is a potential risk related to the investigated metal[46]. The total target hazard quotient (TTHQ) is the arithmetic sum of the target hazard quotient value of individual metal[43].

Lifetime cancer risk (CR) for As was calculated using the cancer slope factor (CSF) of 1.5, provided by EPA for this metal. If cancer risk is above the acceptable lifetime risk – ARL – of 10^{-5}, there is a probability greater than 1 chance over 100,000 of an individual developing cancer[47]. The formula for (cancer risk) is given as:

$$CR = \frac{EF_r \times ED_{total} \times FIR \times C_f \times C_m \times CSF}{BW_a \times AT_n} \qquad (3)$$

Therefore, heavy metals that may accumulate in the tissues of fish should always be monitored to assess their ability to induce harmful effects upon human health when ingested[35]. Life expectancy for individuals in Arabia[48] was taken as 75, an average body weight of 73 kg[49], 110 g/person/day wet weight fish intake[50] and C_f was set equal to 0.208 to convert wet weight into dry weight. The oral reference dose values were Cd (0.001), Cr (0.0015), Cu (0.040), Fe (0.700), Mn (0.140), Ni (0.020), Zn (0.300), Al (0.1405), Pb (0.004), As (0.0003) and Se (0.005) mg/kg/day according to USEPA[51].

The Red sea and the Arabian Gulf coasts are subject to pollution from desalination effluents and brine water[52-54], petrochemical and other industrial wastes[55]. Such activities subject the aquatic environment to getting contaminated with pollutants that affect the biota including fish.

Many studies[56-61] have been conducted to determine the metals content of fish and monitor the extent of pollution due to such anthropogenic activities[62-64]. To our best of knowledge no risk assessment investigation was carried out to evaluate the impact of fish consumption upon inhabitants.

Therefore this study was carried out to determine the concentrations of some metals in the edible part *i.e.* muscles of the two types of fish (*Epinephelus areolatus and Plectropomus maculatus)* caught from the Red sea and Arabian Gulf coasts and compare the level of these metal with regard to species and location. The ED_{mL}, target hazard quotient and cancer risk were calculated to estimate the health risks associated with these types of fish consumption.

EXPERIMENTAL

Sample collection: Ten fresh samples from each of Areolate grouper (*Epinephelus areolatus*) and Coral Trout (*Plectropomus maculatus*) fish were purchased from a fish market in Riyadh, Saudi Arabia. The fish was cleaned with tap water then distilled water and dissected using stainless steel knife to remove the skin and viscera and obtain the edible part *i.e.* muscles. The fish flesh was left to dry in air then put into an oven at 105 °C for an overnight to dry completely. The dry meat was ground to powder using a porcelain mortar and pestle. The meat powder was kept in polythene bags for analysis.

Sample digestion: Wet digestion was carried out according to Djedjibegovic *et al.*[65]. About 2 g of each of the dry meat samples was accurately weighed into a Teflon beaker. A digestion mixture consisting of 6 mL of 65 % HNO_3 (Merck) and 2 mL of 35 % H_2O_2 (Merck) was added to the sample. The beaker content were heated at 130 °C for about 4 h until the sample completely dissolved[2]. The beaker was uncapped and the sample was evaporated to near dryness. Double distilled water was added to dissolve the beaker's residue. The solution was then filtered into 25 mL volumetric flask and completed to the mark with double distilled water.

Sample analysis: Samples were analyzed for all elements under investigation using inductively coupled plasma-atomic emission spectrometry (ICP-ES) model SPECTRO-GENESIS EOP, Germany. Empirical calibration curves were generated using a series of dilutions from a multi-element calibration standard (Spectro-ICP solution: 21 standard elements)[66]. Accuracy was checked by analysis of certified reference materials MA-A-2 (TM), fish flesh homogenate and MA-B-3 (TM) fish tissue from International Atomic Energy Agency (IAEA), Vienna (Table-1). From these results it could be concluded that the analyzed material was in the value range of the certified material. Two way analysis of variance (ANOVA) was performed, in

TABLE-1
CERTIFIED AND OBSERVED VALUES FOR ELEMENTAL CONCENTRATION OF REFERENCE MATERIALS BY ICP-ES

Element	Certified value	Observed value	Recovery (%)
MA-A-2 (TM)			
Cd	0.066 ± 0.004	0.062 ± 0.01	93.94
Ni	1.1 ± 0.20	1.17 ± 0.1	106.36
Cr	1.3 ± 0.1	1.25 ± 0.1	96.15
Cu	4 ± 0.1	4.1 ± 0.25	102.50
Zn	33 ± 1.0	32 ± 0.5	96.97
Mn	0.81 ± 0.04	0.80 ± 0.02	98.77
As	2.6 ± 0.1	2.55 ± 0.20	98.08
MA-A-2 (TM)			
Pb	4.62 ± 0.64	4.80 ± 0.60	103.90
Cu	3.08 ± 0.36	3.15 ± 0.0.42	102.40

order to evaluate differences in accumulation patterns between the two fish species and sites. A correlation between the tested elements was calculated. Values were significantly different at $p > 0.05$.

RESULTS AND DISCUSSION

Metals concentrations in fish samples: The trace elements contents of the four fish samples are displayed in Table-2. The elements concentration ranges were 0.06-0.75, 0.25-2.12, 1.62-5.12, 7.44-21.34, 0.25-1.00, 0.61-4.24, 27.20-166.50, 3.00-11.73, 0.62-6.13, 4.24-36.75 and 0.562-2.388 μg g^{-1} for Cd, Cr, Cu, Fe, Mn, Ni, Zn, Al, Pb and Se respectively. Species-wise it can be seen that *P. maculatus* from both study areas bioaccumulate more Cd, Cr, Fe, Mn, Ni, Pb, As and Se compared to *E. areolatus*. Among the elements studied Zn was present in the highest concentration in all of the fish samples. This data is similar to the 46.4-260.6 μg g^{-1} [57] and 70-180 μg g^{-1} [63] ranges reported for fish from the study area.

TABLE-2
TRACE ELEMENTS CONCENTRATIONS (μg g^{-1} dry wt) IN FISH SAMPLES

Element	Sample 1R (n =10)	Sample 2R (n =10)	Sample 1G (n =10)	Sample 2G (n =10)
Cd	0.06±0.01	0.13±0.03	Nil	0.75±0.14
Cr	0.50±0.12	0.75±0.21	0.25±0.06	2.12±0.46
Cu	2.64±0.52	2.50±0.62	1.62±0.48	5.12±1.28
Fe	11.50±3.21	17.38±4.16	7.44±1.73	21.34±4.14
Mn	0.81±0.08	1.00±0.11	0.25±0.07	0.87±0.11
Ni	0.61±0.09	1.25±0.32	1.00±0.09	4.24±0.87
Zn	62.58±12.31	49.00±14.60	27.20±6.24	166.50±25.46
Al	11.73±3.20	10.38±0.83	3.00±0.61	9.61±2.10
Pb	1.39±0.25	6.13±1.02	0.62±0.15	4.87±1.15
As	33.18±7.54	36.75±7.38	4.24±1.35	21.70±5.61
Se	1.41±0.36	2.38±0.42	0.56±0.16	2.35±043

Nil = Below detection limit, [1 = *E. areolatus,* 2 = *P. maculatus*, R = Red sea, G = Arabian Gulf]

On the other hand, Cd was the lowest in all samples. In an earlier study, 0.2-0.9 μg g^{-1} Cd was determined[61] which lies in the same limit with our data. The concentration of Cd in this work is less than fish contents from UAE (7.19 and 9.94 μg g^{-1}) and Oman (109 and 195 μg g^{-1}) measured by de Mora *et al.*[62] who attributed their high values to pollution in the study areas.

A concentration of 1.1-2.9 and 3.96 ± 0.98 μg g^{-1} of Cu was determined by Zyadah & Almoteiry[61] and Ashraf[60] for fish from the Gulf. The values determined in this work agree with those findings.

The Pb content of the fish samples from the Gulf found in this study is comparable with the (0.9-3.2 μg g^{-1}*)* and 3.19 ± 2.03 data of Al-Sayed *et al*.[57] and Ashraf[60], respectively.

Both fish species from the Red sea accumulate more As. The As content determined in this study for fish from the Gulf was (0.62-4.87 μg g^{-1}) is higher than the 1.70 μg g^{-1} mean reported by Madany *et al.*[58] and (0.07-0.6) μg/g by Zyadah and Almoteiry[61] for fish from the same area. In contrast the As content for fish from the Red sea agrees with the 20.20-43.3 μg/g content[64]. Arsenic is a natural source contaminant present in rocks. Anthropogenic activities such as use of pesticide and industrial emission can increase its concentration in the environment[21,67]. The soil of the Red sea greatly consists of rock as part of The Great African Rift[68] whereas that of the Gulf is sandy. This may, but not certain, justify the high value of As content in fish from the Red sea. Some authors[28] attributed a high As content to the fact that water near sediments contains more As than surface water. While de Gieter *et al.*[69] found that fish feeding on benthic organisms and small fish accumulate more As than those feeding on large fish. It may be the difference of habitat, sediment composition and feeding pattern of fish is influencing their As content.

Selenium is an essential nutritional element with anti-oxidant and cancer prevention properties. An amount of 55 μg of it is recommended for adults[70]. In this study, the Se contents of fish are high and may even be toxic to humans[71]. High Se was measured in sponges from the Red sea[72] as they harbor symbiotic bacteria for which Se is an essential element. Thus Se can get transferred to fish though food chain. Afonso *et al*.[30] found 0.18-0.57 Se in fish from the Mediterranean. One benefit of Se is its ability to modify toxic effects of trace elements[73] and methyl mercury[74].

The two tailed t-test results should there is significant difference between the species as well as location. The p value was 0.988 between samples (1R) and (2R), 0.263 samples (1G) and (1G) indication a significant difference between the species in the Red sea and the Gulf. Similarly p value between samples 1R and 1G was 0.201 and between sample 2R and 2G was 0.526 depicting a significant difference location wise. The correlation displayed in Table-3 indicates that analyzed element are generally correlated significantly.

From Table-3, it can be observed that Cd, Cr, Cu, Fe, Ni and Zn are significantly correlated. This may indicate their being of the same source. These elements are of anthropogenic origin coming from human activities. With the exception of Al, arsenic is insignificantly correlated to all other elements. This may support that As may have come from natural sources. Lead is moderately correlated to other elements.

It can be seen from Table-4 that there is a diversity in metal contents of fish around the globe. Moreover the results obtained in this study agrees with most of the international data especially the nearby areas like the Mediterranean[75], Turkey[76,77] and Portugal[30].

Estimated daily intake per meal size of fish (ED_{mL}): The evaluation of estimated daily intake per meal size that

TABLE-3
CORRELATION BETWEEN HEAVY METALS IN FISH SAMPLES

	Cd	Cr	Cu	Fe	Mn	Ni	Zn	Al	Pb	As	Se
Cd	1	0.996	0.977	0.842	0.413	0.986	0.981	0.271	0.531	0.033	0.642
Cr		1	0.983	0.887	0.494	0.972	0.977	0.344	0.598	0.121	0.711
Cu			1	0.859	0.532	0.930	0.995	0.448	0.524	0.192	0.692
Fe				1	0.797	0.790	0.810	0.587	0.883	0.491	0.953
Mn					1	0.291	0.450	0.921	0.800	0.917	0.925
Ni						1	0.941	0.116	0.502	-0.11	0.568
Zn							1	0.381	0.449	0.106	0.620
Al								1	0.504	0.936	0.725
Pb									1	0.580	0.942
As										1	0.708
Se											1

TABLE-4
METALS CONCENTRATION (μg g^{-1}) IN FISH FROM LITERATURE

Sampling location	Cd	Cr	Cu	Fe	Mn	Ni	Zn	Al	Pb	As	Se	Reference
Malaysia	0.03-0.05	-	1.01-1.69	-	-	3.49-3.86	20.58-26.13	-	0.26-0.99	-	-	26
Brazil	0.001-0.09		1.2-2.9	1.6-7.5	0.3-1.7		2.7-9.3	49.1-215.5	0.04-0.3	0.1-6.1	0.002-0.10	73
Turkey	0.01-0.75		1.0-2.5	36.1-110	2.76-9.10		11.6-63.5			0.11-0.32	0.19-0.85	76,77
	0.08-4.14	0.21-3.13	0.04-3.56	0.82-11.28	0.33-4.01	2.46-12.88	0.60-8.70	0.07-2.64	1.12-6.95			78
Portugal	0.001-0.008						2.8-4.1		0.04-0.8	13-46	0.27-0.37	30
China	0.004-0.03	0.11-2.55	0.36-6.44				6.15-48.6		0.003-0.28			79
Ghana	0.17-0.32		0.10-0.35	5.50-18.1	20.95-32.30	0.032-0.55	18.25-23.15		4.32-10.85			44

depends on the amount of seafood ingested and the concentration of metals under study is shown in Table-5. A comparison with tolerable intake (TI) proposed by Joint FAO/WHO Expert Committee on Food Additive[80] was made. The ED_{mL} is higher than TI for Ni and Pb for *P. maculatus* from the Gulf. The ED_{mL} is also higher than TI for Pb for *P. maculatus* from the Red sea. The ED_{mL} is lower than TI for all elements for *E. areolatus* from the both study areas.

TABLE-5
ESTIMATED DAILY INTAKE PER MEAL SIZE OF FISH (ED_{mL}) COMPARED WITH TOLERABLE INTAKE (μg/person/day) SUGGESTED BY (JECFA) [Ref. 80,81]

Element	TI	Sample 1R	Sample 2R	Sample 1G	Sample 2G
Cd	58.3*	1.37	2.97	0	17.16
Cr	50-200	11.44	17.16	5.72	48.51
Cu	700	60.40	57.20	37.07	117.15
Fe	800	263.12	397.65	170.23	488.26
Mn	1800-2300	18.53	22.88	5.72	19.91
Ni	300	13.96	28.60	22.88	97.01
Zn	8000-11000	1431	1121.12	622.336	3809.52
Al	nd.	268.38	237.49	68.64	219.88
Pb	105*	31.80	140.25	14.19	111.42
As	21-560*	22.77	25.22	2.91	14.89
Se	55	32.26	54.45	12.81	53.77

*Toxological limit (μg day^{-1}) [Ref. 85]

From Table-5 it can be seen that ED_{mL} for Fe is below the provisional maximum tolerance intake of 800 μg day^{-1} set by JECFA[81]. For Mn ED_m was 5.72- 22.88 μg day^{-1} which is also less than the limit set by USEPA[82], Canada[83] and Noel *et al.*[84]. The ED_{mL} for Ni is 97.01 μg day^{-1} is less than the limitset by WHO[48].

For Cd, Pb and As the toxological limit set by IOM[85] was employed to evaluate their toxic effects as they don't contribute to the nutritional value of food. From Table-5 it is clear that the ED mL for the three element is less than the threshold set indicating no hazards will be posed to consumers by eating the fish under study.

The daily dietary intake of Zn and Cu recommended for adults were 33 and 6.5 mg, respectively[86]. The highest average daily intake of 3.809 mg Zn and 0.117 mg Cu are less than the recommended values.

Target hazard quotient for metals: Table-6 shows the values of the target hazard quotient for the toxic elements calculated according to equation (2) for 7, 5, 3 and 1 meal/week exposure level.

Target hazard quotient values with respect to Cd, Pb an As for all fish samples are less than 1 for all exposure levels. This indicates that no risk is imposed due to the intake of the mentioned metals. The target hazard quotient values reported for toxic elements Cd and Pb due to fish consumption in Ghana[44] were less than the values reported here. This may be due to the higher fish intake in the Gulf area of 110 g/person/day relative to the low intake of 48 g/person/day in Ghana[44]. Target hazard quotient values reported in this study are comparable with 0.14 and 0.34 and values for Cd and Pb for fish consumption in Malaysia[26]. Target hazard quotient values reported here are less than those reported by Copat *et al.*[75] for the consumption of food at the Mediterranean sea.

TABLE-6
TARGET HAZARD QUOTIENT OF INDIVIDUAL TOXIC ELEMENTS IN MUSCLES OF FISH SAMPLES FROM RED SEA AND ARABIAN GULF

Element	Exposure level (day/week)	Red sea		Arabian Gulf	
		Sample 1R	Sample 2R	Sample 1G	Sample 2G
Cd	7	0.019	0.015	-	0.073
	5	0.013	0.010	-	0.052
	3	0.008	0.006	-	0.031
	1	0.003	0.002	-	0.010
Pb	7	0.109	0.479	0.048	0.381
	5	0.078	0.342	0.035	0.272
	3	0.047	0.205	0.021	0.163
	1	0.016	0.068	0.007	0.054
As*	7	0.890	0.986	0.151	0.707
	5	0.636	0.704	0.108	0.505
	3	0.381	0.422	0.065	0.303
	1	0.127	0.140	0.021	0.101

*As calculations were made by assuming the inorganic As the 3 % of the total concentration [Ref. 87]

Lifetime cancer risk (CR) for As: The cancer risk of arsenic (Table-7) are higher than the threshold of 10^{-5} set by US-EPA[47] for all exposure frequency for all fish samples except one meal per day. High cancer risk values were reported by Saha and Zaman[8] for fish consumption in Bangladesh as that was attributed to water contamination by As. Copat *et al.*[75] also reported high values of target hazard quotient and cancer risk of As for fish consumption in the Mediterranean. To reduce the risk, the researchers[75] advised minimizing the number of fish containing meals. Similarly, the number of fish containing meals should be reduced to avoid health risk due to these type of fish consumption.

TABLE-7
CANCER RISK OF ARSENIC IN MUSCLES OF FISH SAMPLES FROM RED SEA AND ARABIAN GULF

Exposure level (day/week)	Red sea		Arabian Gulf	
	Sample 1R	Sample 2R	Sample 1G	Sample 2G
7	3.95×10^{-4}	4.37×10^{-4}	6.86×10^{-5}	3.12×10^{-4}
5	2.81×10^{-4}	3.12×10^{-4}	4.89×10^{-5}	2.22×10^{-4}
3	1.68×10^{-4}	1.87×10^{-4}	2.91×10^{-5}	1.33×10^{-4}
1	5.62×10^{-5}	6.24×10^{-5}	9.78×10^{-6}	4.37×10^{-5}

Conclusion

The concentration of some trace elements was determined in two types of fish species (*Epinephelus areolatus* and *Plectropomus maculatus)* from the Red sea and Arabian Gulf coasts. Elevated concentration of some elements was observed in *P. maculatus* from both study areas. High As was detected in both species from the Red sea. The health risk assessment parameters ED_{mL}, target hazard quotient and cancer risk were calculated to evaluate the health effects associated with these types of fish consumption. The target hazard quotient values were less than unity for the toxins As, Cd and Pb at different exposure levels. The cancer risk value for As was higher than the 10^{-5} threshold set by health concerned bodies. It can be concluded from the study that there is no risk associated with consuming these types of fish.

ACKNOWLEDGEMENTS

The authors thank College of Science, AI Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia for providing the necessary facilities to complete this work.

REFERENCES

1. C. Cahu, P. Salen and M. de Lorgeril, *Nutr. Metab. Cardiovasc. Dis.*, **14**, 34 (2004).
2. H. Altundag and M. Tuzen, *Food Chem. Toxicol.*, **49**, 2800 (2011).
3. IOM, Seafood Choices: Balancing Benefits and Risks, National Academy Press, Washington DC (2007).
4. FAO, The State of World Fisheries and Aquaculture (SOFIA), Food and Agriculture Organization of the United Nations, Rome (2010).
5. T. Guérin, R. Chekri, C. Vastel, V. Sirot, J.-L. Volatier, J.-C. Leblanc and L. Noël, *Food Chem.*, **127**, 934 (2011).
6. U. Celik and J. Oehlenschlager, *Food Chem.*, **87**, 343 (2004).
7. J. Anderson and C. Fitzgerald Iron: An Essential Nutrient (2010); http://www.ext.colostate.edu/pubs/foodnut/09356.html (assessed 20/03/13).
8. N. Saha and M.R. Zaman, *Environ. Monit. Assess.*, **185**, 3867 (2013).
9. NAS-NRC, National, Drinking Water and Health, Academy of Sciences-National Research Council National Academic Press, Washington D.C. (1982).
10. FAO, FAO Fishery Circular No. 464, pp. 5-100 (1983).
11. D. McCluggage, Heavy Metal Poisoning, NCS Magazine, Published by The Bird Hospital, CO, U.S.A. (1991). www.cockatiels.org/articles/Diseases/metals.html.
12. H. Özparlak, G. Arslan and E. Arslan, *Turk. J. Fish. Aquat. Sci.*, **12**, 761 (2012).
13. S. Altamura and M.U. Muckenthaler, *J. Alzheimers Dis.*, **16**, 879 (2009).
14. J.W. Spears, *Proc. Nutr. Soc.*, **59**, 587 (2000).
15. H. Lu, X. Shi, M. Costa and C. Huang, *Mol. Cell. Biochem.*, **279**, 45 (2005).
16. T. Stromgren, *J. Exp. Mar. Biol. Ecol.*, **43**, 107 (1980).
17. S.V. Verstraeten, L. Aimo and P.J. Oteiza, *Arch. Toxicol.*, **82**, 789 (2008).
18. M.I. Castro-Gonzalez and M. Mendez-Armenta, *Environ. Toxicol. Pharmacol.*, **26**, 263 (2008).
19. IPCS, Arsenic and Arsenic Compounds, World Health Organization, International Programme on Chemical Safety (Environmental Health Criteria), Geneva, edn 2, pp. 224 (2001).
20. U.S. Environmental Protection Agency (USEPA), IRIS Substance File for Arsenic, Inorganic (2001).
21. ATSDR, Toxicological Profile for Arsenic, Agency for Toxic Substance and Disease Registry, Atlanta, Georgia (2007).
22. H.D. Belitz, W. Grusch and P. Schiebrle, Food Chemistry, Springer-Verlag, Berlin (2004).
23. M.F. Hughes, B.D. Beck, Y. Chen, A.S. Lewis and D.J. Thomas, *Toxicol. Sci.*, **123**, 305 (2011).
24. K.M. Lokuge, W. Smith, B. Caldwell, K. Dear and A.H. Milton, *Environ. Health Perspect.*, **112**, 1172 (2004).
25. Y. Yu, X. Wang, D. Yang, B. Lei, X. Zhang and X. Zhang, *Food Chem. Toxicol.*, **69**, 86 (2014).
26. A. Taweel, M. Shuhaimi-Othman and A.K. Ahmad, *Ecotoxicol. Environ. Saf.*, **93**, 45 (2013).
27. C. Afonso, H.M. Lourenco, A. Dias, M.L. Nunes and M. Castro, *Food Chem.*, **101**, 120 (2007).
28. M.M. Storelli and G.O. Marcotrigiano, *Food Addit. Contam.*, **17**, 763 (2000).
29. P. Anacleto, H.M. Lourenço, V. Ferraria, C. Afonso, M. Luísa Carvalho, M. Fernanda Martins and M. Leonor Nunes, *J. Aquat. Food Prod. Technol.*, **18**, 32 (2009).
30. C. Afonso, H. Lourenco, C. Cardoso, M.N. Bandarra, M.L. Carvalho, M. Castro and M.L. Nunes, *Food Chem.*, **137**, 99 (2013).
31. X.-Z. Meng, E.Y. Zeng, L.-P. Yu, Y. Guo and B.-X. Mai, *Environ. Sci. Technol.*, **41**, 4882 (2007).
32. F. Aydemir, H. Altundag and M. Imamoglu, *Fresenius Environ. Bull.*, **21**, 3589 (2012).
33. L. Dsikowitzky, M. Mengesha, E. Dadebo, C.E.V. de Carvalho and S. Sindern, *Environ. Monit. Assess.*, **185**, 3117 (2013).
34. M.W. Aktar, D. Sengupta and A. Chowdhury, *Environ. Monit. Assess.*, **181**, 51 (2011).

35. S. Sivrikaya, H. Altundag, M. Zengin and M. Imamoglu, *Sep. Purif. Technol.*, **46**, 2032 (2011).
36. M. Turkmen, A. Turkmen, Y. Tepe, Y. Tore and A. Ates, *Food Chem.*, **113**, 233 (2009).
37. R.D. Cardwell, Brancato, J. Toll, D. Deforest and I. Tear, *Environ. Toxicol. Chem.*, **18**, 567 (1999).
38. J.P. Giesy, K.R. Solomon, J.R. Coates, K.R. Dixon, J.M. Giddings and E.E. Kenaga, *Rev. Environ. Contam. Toxicol.*, **160**, 1 (1999).
39. K.R. Solomon, B. Baker, R.B. Richards, D.R. Dixon, S.J. Klaine, T.W. Lapoint, R.J. Kendall, C.P. Weisskopf, J.M. Giddings, J.P. Giesy, L.W. Hall Jr. and W.M. Williams, *Environ. Toxicol. Chem.*, **15**, 31 (1996).
40. X.L. Wang, S. Tao, R.W. Dawson and F.L. Xu, *Environ. Res.*, **90**, 201 (2002).
41. C. Copat, F. Bella, M. Castaing, R. Fallico, S. Sciacca and M. Ferrante, *Bull. Environ. Contam. Toxicol.*, **88**, 78 (2012).
42. M.S. Rahman, A. Molla, N. Saha and A. Rahman, *Food Chem.*, **134**, 1847 (2012).
43. L.-C. Chien, T.-C. Hung, K.-Y. Choang, C.-Y. Yeh, P.-J. Meng, M.-J. Shieh and B.-C. Han, *Sci. Total Environ.*, **285**, 177 (2002).
44. O. Akoto, E.F. Bismark, G. Darko and E. Adei, *Int. J. Environ. Res.*, **8**, 403 (2014).
45. R.M. Awadallah, A.E. Mohamed and S.A. Jaber, *Chem. Lett.*, **95**, 450 (1985).
46. S. Khan, Q. Cao, Y.M. Zheng, Y. Huang and Y.G. Zhu, *Environ. Pollut.*, **152**, 686 (2008).
47. USEPA, Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories, Risk Assessment and Fish Consumption Limits, United States Environmental Protection Agency, edn 3, Vol. 2 (2000).
48. WHO, Guidelines for Drinking Water Quality, Recommendations, Geneva, Switzerland, edn 2, vol. 1 (1993).
49. L. Bashraheel, Saudi Arabia Ranks 21 Among the World's 'Fattest' Countries, Saudi Gazette, 22 June 2012.
50. O.M. Abdulrahman, Food Consumption Pattern in the Eastern Mediterranean Region, First Edition, Arab Center for Nutrition, Manama, Bahrain (2011).
51. USEPA, United States Environmental Protection Agency, Risk-Based Concentration Table, Philadelphia (2009).
52. S. Lattemann and T. Höpner, *Desalination*, **220**, 1 (2008).
53. A. Hashim and M. Hajjaj, *Desalination*, **182**, 373 (2005).
54. T. Hoepner and S. Lattemann, *Desalination*, **152**, 133 (2002).
55. P. Literathy, N. Khan and O. Linden, in eds.: N. Khan, M. Munawar and A. Price, Oil and Petroleum Industry, The Gulf Ecosystem: Health and Sustainability, Backhuys Publishers, Leiden, pp. 127–156 (2002).
56. M. Al-Yousuf, M. El-Shahawi and S. Al-Ghais, *Sci. Total Environ.*, **256**, 87 (2000).
57. H. Al-Sayed, J. Al-Saad, I. Madany and D. Al-Hooti, *Int. J. Environ. Stud.*, **50**, 237 (1996).
58. I.M. Madany, A.A.A. Wahab and Z. Al-Alawi, *Water Air Soil Pollut.*, **91**, 233 (1996).
59. I. Al-Saleh and N. Shinwari, *Chemosphere*, **48**, 749 (2002).
60. W. Ashraf, *Environ. Monit. Assess.*, **101**, 311 (2005).
61. M.A. Zyadah and M.G. Almoteiry, *Asian Transac. Basic Appl. Sci.*, **2**, 2221 (2012).
62. S. de Mora, S. Fowler, E. Wyse and S. Azemard, *Mar. Pollut. Bull.*, **49**, 410 (2004).
63. I.N. Al-Suwiti, *Aquat. Biol. Fish*, **13**, 1110 (2009).
64. A.A. Ali, E.M. Elazein and M.A. Alian, *J. Appl. Environ. Biol. Sci.*, **1**, 453 (2011).
65. J. Djedjibegovic, T. Larssen, A. Skrbo, A. Marjanovic and M. Sober, *Food Chem.*, **131**, 469 (2012).
66. Y. Yi, Z. Yang and S. Zhang, *Environ. Pollut.*, **159**, 2575 (2011).
67. V. Sirot, T. Guérin, J.-L. Volatier and J.-C. Leblanc, *Sci. Total Environ.*, **407**, 1875 (2009).
68. G.F. Brown, *Philos. Trans. R. Soc. Lond.*, **267**, 75 (1970).
69. M. De Gieter, M. Leermakers, R. Van Ryssen, J. Noyen, L. Goeyens and W. Baeyens, *Arch. Environ. Contam. Toxicol.*, **43**, 406 (2002).
70. Institute of Medicine. Dietary Reference Intake for Vitamin C, Vitamin E, Selenium and Carotenoids, Food and Nutrition Board, The National Academies Press, Washington DC (2001).
71. E. Al-Saleh, M. Nandakumaran, J. Al-Harmi, T. Sadan and H. Al-Enezi, *Biol. Trace Elem. Med. Biol*., **113**, 113 (2006).
72. B. Mayzel, J. Aizenberg and M. Ilan, *PLoS ONE*, **9**, e95775 (2014).
73. R.J. Medeiros, L.M.G. dos Santos, A.S. Freire, R.E. Santelli, A.M.C.B. Braga, T.M. Krauss and S.C. Jacob, *Food Contr.*, **23**, 535 (2012).
74. A.M. Peraza, F. Ayala-Fierro, D.S. Barber, E. Casarez and L. Rael, *Environ. Health Perspect.*, **106**, 203 (1998).
75. C. Copat, G. Arena, M. Fiore, C. Ledda, R. Fallico, S. Sciacca and M. Ferrante, *Food Chem. Toxicol.*, **53**, 33 (2013).
76. M. Tuzen, *Food Chem. Toxicol.*, **47**, 1785 (2009).
77. D. Mendil, O.F. Unal, M. Tuzen and M. Soylak, *Food Chem. Toxicol.*, **48**, 1383 (2010).
78. A. Turkmen, M. Turkmen, Y. Tepe and I. Akyurt, *Food Sci.*, **91**, 167 (2005).
79. X. Wang, T. Sato, B. Xing and S. Tao, *Sci. Total Environ.*, **350**, 28 (2005).
80. JECFA, Joint FAO/WHO Expert Committee on Food Additives, Evaluation of Certain Food Additives and Contaminants, 26th Report of the Joint FAO/WHO Expert Committee on Food Additives, Technical Report Series 683, Geneva, Switzerland (1982).
81. JECFA, Joint FAO/WHO Expert Committee on Food Additives, Evaluation of Certain Food Additives and Contaminants, 27th Report of the Joint FAO/WHO expert Committee on Food Additives, Technical Report Series 696, Geneva, Switzerland (1983).
82. USEPA, United States Environmental Protection Agency, Risk-Based Assessment Regional Screening Level (RSL) Table, Philadelphia (2013).
83. Health Canada, Federal Contaminated Site Risk Assessment in Canada, Part II, Health Canada Toxicological Reference Values (TRVs) and Chemical-Specific Factors, Version 2 (2010).
84. L. Noël, J.-C. Leblanc and T. Guérin, *Food Addit. Contam.*, **20**, 44 (2003).
85. Institute of Medicine-IOM, Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc, National Academy Press, Washington DC (2002).
86. R. Raghunath, R.M. Tripathi, A.V. Kumar, A.P. Sathe, N. Khandekar and K.S.V. Nambi, *Environ. Res.*, **80**, 215 (1999).
87. FSA, Total Diet Study: Total and Inorganic Arsenic in Food, Food Surveillance Information Sheet (2004).