Measurement of the Natural Radioactivity of the Local Fish of the Marshes of Southern Iraq (Al-Hamar, Al-Masahab, Middle and Al-Hawizeh) and Assessing the Radioactive Doses and their Risks for Consumers

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Abstract

In Iraq, potential marshes radiological contamination is a local problem and has a particular concern. Effluents from different sources directly enters marshes of the region may contain radioactive materials and may pose a serious potential threat to the local community, in addition to aquatic ecosystems. Using gamma-ray spectrometry system, a comprehensive study was carried out on the radioactivity of ^{238}U, ^{232}Th, ^{40}K, and ^{137}Cs in fish samples collected from Al-Hawizeh, Al-Hamar, Central and Al-Masahab marshes. The radiometric analysis showed a noticeable variety in the levels of natural and artificial radionuclides in the fish samples. Activity concentrations were found to be ranged from 4.33 to 20.65 Bq/kg for ^{238}U, 2.42 to 20.98 Bq/kg for ^{232}Th, 1.32 to 9.42 Bq/kg for ^{137}Cs, and 66.78 to 235.78 Bq/kg for ^{40}K. Anthropogenic radionuclide (^{137}Cs) was detected in the fish samples at lowest levels, which indicates aquatic biota are potentially subjected to radiological pollution. The estimated total effective dose and radiation-derived risk were calculated and compared with the corresponding permissible safety limits. The estimated radiation doses resulting from fish consumption were found to be vary widely depending on the concentrations of radioactive nuclides in the fish products, ranged from 2.76×10^{-5} Sv/y at Al-Hawizeh marsh, to 5.13×10^{-5} Sv/y at Al-Masahab marsh. Fish consumption would contribute a potential radiation risk range from 1×10^{-4} to 2×10^{-4}. These risk values are only a small fraction of the corresponding risk limit (10^{-3}). It was found that consuming the fish from the investigated Iraqi marshes may not cause adverse health impacts. Accordingly, the consumption of the studied fish species should be considered safe for human health.

Keywords: Iraqi marshes, radioactive doses, radiation risks.
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1. Introduction

The Mesopotamian Marshes, also known as the Iraqi Marshes (Fig. 1), are a wetland area located in Southern Iraq. Historically, the marshlands mainly composed of the separate but adjacent Central, Hawizeh and Hammar Marshes, providing habitat important populations of wildlife. Draining of portions of the marshes began in the 1950s and continued through the 1970s to reclaim land for agriculture and oil exploration. Before 2003, the marshes were drained to 10% of their original size. After 2003, the marshes have partially recovered but drought along with upstream dam construction and operations in Turkey, Syria and Iran have hindered the process. Since 2016, the Mesopotamian marshes have been listed as an UNESCO Heritage Site (Wikipedia, 2020).

Naturally occurring and human-made radionuclides exist in the environment in the air we breathe and in the water we drink. Not surprisingly, these radionuclides can be found in varying concentrations in fishery products. Fish species are potential bio-indicators when they accumulate the target radionuclides from surrounding waters. Monitoring of radionuclides levels in fish is of great importance due to their significant contribution to the natural radiation dose received by human beings consuming those (Biswas *et al*, 2021). The aim of this study is to assess the potential radioactive doses and their risks for consumers associated with fish consumption for fish species common in Iraqi marshes.

Fig. 1. Map of the Iraqi Marshes

2. Materials and Methods

2.1 Samples Collection, Preparation and Analysis

The studied field locations were openly accessible, and the fish species collected did not belong to any protected species, so permissions were not required at the time of collecting samples from the studied locations. The investigated fish species were collected from the marshes during January-February 2022. The fish samples were obtained from fishing boats operating in the locations of interest. A total of 25 fish samples were chosen for investigation. The studied fish species are locally available and commercially important for human consumption.

All the fish samples were labelled, stored in ice, and, on the same day, transported to the laboratory and washed with clean water. Afterwards, the samples were dried at 70 ^{o}C for 1 hour, packed in polyethylene bags, and stored in a refrigerator of the analytical laboratory to avoid degradation, spoiling, contamination, or any other decomposition until further treatment and analysis were done. For the analysis of radionuclides activity concentrations, all the animals were used in their entirety, since the analysis was intended to quantify the activity concentrations of each fish species. Each sample was sun-dried to remove the extra water and subsequently oven-dried at about 70 ^{o}C to obtain a constant weight. The samples were then weighed to determine the dry weight. Finally, the dried samples were crushed, sieved for homogeneity, and stored in clean and dry uncontaminated empty cylindrical plastic Marinelli containers of uniform size, sealed with wide vinyl adhesive tapes around their screw necks to air tighten for succeeding uses (Biswas *et al*, 2021). For the natural and artificial radioactivity measurement dose conversion factor (DCF, Sv/Bq). Thus, the ingestion dose is given by (Biswas *et al*, 2021; ICRP, 1994; Pulhani, et al, 2005):

Annual effective dose (Sv/y) = activity concentration (Bq/kg) × annual food intake (kg/y) × DCF (Sv/Bq) … (2)

For adults (age > 17 year), fish consumption rate is about 8 kg/y. DCF is 6.2×10^{-9} Sv/Bq for ^{40}K, 1.3×10^{-8} Sv/Bq for ^{137}Cs, 2.3×10^{-7} Sv/Bq for ^{232}Th, and 4.5×10^{-8} Sv/Bq for ^{238}U (IAEA, 2014).

2.3 Radiation Risk Assessment

Cancer is called a life-threatening disease, and the percentage of this disease increases all over the world, including in Iraq, due to various reasons. One of the reasons is the effect of radiation on the biological cells, which contributes to a greater extent to increasing cancer incidence. An effort was made to assess the excess lifetime cancer risk due to the ingestion of marshes fish using the procedure proposed by the United States Environmental Protection Agency (USEPA) (Pawel *et al*, 2007). The following equation was used to calculate the excess lifetime cancer risk (Khandaker *et al*, 2015; Asaduzzaman *et al*, 2015):

$$ELCR = A_{ir} \times A_{ls} \times R_c \quad \dots (3)$$

where ELCR: is the excess lifetime cancer risk, A_{ir} : the annual intake of radionuclide (Bq), A_{ls} : the average lifespan (72 year (Biswas *et al*, 2021)), and R_c: the mortality cancer risk coefficient (Bq^{-1}). The values of mortality cancer risk coefficients are 9.56×10^{-9} Bq^{-1} for $^{226}Ra(^{238}U)$, 2.45×10^{-9} Bq^{-1} for ^{232}Th, 5.89×10^{-10} Bq^{-1} for ^{40}K, and 7.5×10^{-10} Bq^{-1} for ^{137}Cs (Pawel *et al, 2007*; Khandaker *et al, 2015*) . The acceptable ELCR limit is 10^{-3} for radiological risk in general (Biswas *et al*, 2021; Asaduzzaman *et al*, 2015; Patra *et al*, 2013).

of each fish sample, about 500 g of dried fish samples were weighed and placed in individual plastic Marinelli containers. The fish samples were kept 4 weeks before the analysis in airtight conditions to allow secular equilibrium between thorium and radium and their short-lived progenies (Biswas *et al*, 2021; Gorur *et al*, 2012). The collected fish samples were analyzed for radioactivity using gamma-ray spectrometry system (HpGe-Li detector). Concentrations of total dissolved solids (TDS) were measured in the field using field TDS meter. The activity concentrations (Bq/kg) of the natural and anthropogenic radionuclides in the analyzed fish samples were evaluated by the following equation (Biswas *et al*, 2021; Amin *et al,* 2013):

$$A = \frac{CPS}{\varepsilon_\gamma \times I_\gamma \times M} \quad \dots (1)$$

where CPS = net count per second (i.e., background subtracted), ε_γ = detector efficiency of the specific gamma-ray, I_γ = intensity of the gamma-ray, and, M= mass of the sample in grams. The errors of the measurements were expressed in terms of the standard deviation of the ±1σ level.

2.2 Radiation Dose Assessment

Annual effective dose is a useful concept that enables the radiation doses from different radionuclides and from different types of sources of radioactivity to be added. Estimation of the radiation-induced health effects associated with the intake of radionuclides in the body is proportional to the total dose delivered by the radionuclides while resident in the various organs. Radiation doses of ingestion were obtained by measuring radionuclide activity in fish samples (Bq/kg) and multiplying these by the masses of food consumed over a certain period (kg/y) and radionuclide-specific phosphate rocks may contain relatively highest uranium concentrations.

To assess radiation doses resulting from long-term fish consumption, the activity concentration values were averaged over broad marsh areas. This is because people normally get fish products from various sources during a year, and marsh fishes migrate significant distances during their lifecycles and in different seasons. The estimated annual effective doses due to intake of ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K from the consumption of fish from the investigated Iraqi marshes are presented in table 6. The total annual effective doses were found to be 1.9 to 3.6 times less than the reference dose level of 0.1 mSv/y (Oxford University Press, 2013) normally proposed for a single type of food intake, such as fish consumption in the current consideration, indicating no threat to the consumers for non-emergency conditions. The estimated radiation risk values for all investigated Iraqi marshes are shown in table 6. All of the obtained radiation risk values were lower than the acceptable radiation risk limit of 10^{-3} (Biswas *et al*, 2021; Asaduzzaman *et al*, 2015, Patra *et al*, 2013), indicating no radiological health hazard to the consumers.

3. Results and Discussion

Results of radiometric analysis for fish samples collected from Al-Hawizeh, Al-Hamar, Central and Al-Masahab marshes are shown in tables 1-4. In all studied fish samples, activity concentrations ranged from 4.33 to 20.65 Bq/kg for ^{238}U, 2.42 to 20.98 Bq/kg for ^{232}Th, 1.32 to 9.42 Bq/kg for ^{137}Cs, and 66.78 to 235.78 Bq/kg for ^{40}K. Generally, ^{40}K shows highest activity concentrations than those of the other radionuclides for all samples, while ^{137}Cs shows relatively lowest values. In Iraq, ^{137}Cs exist in the environment as a consequence of the Chernobyl accident in Ukraine (1986) (Kamal *et al*, 2011). Not surprisingly, this artificial radionuclide can be found in varying concentrations in fishery products.

Radionuclides activity concentrations for fish samples collected from Al-Masahab marsh were generally higher than those detected in other investigated marshes (Fig. 2). It was noted that the radioactivity levels of fish samples increases with increase of the total dissolved salts, according to results of TDS measurements shown in Table 5. Fish samples grown on marshes waters descending from areas containing

Table 1. Results of radiometric analysis for fish samples collected from Al-Hawizeh marsh.

No.	Fish type (local name in Iraq)	Radioactivity levels (Bq/kg ± σ)			
		^{238}U	^{232}Th	^{137}Cs	^{40}K
1	Al-buni	6.42 ± 0.45	2.42 ± 0.4	2.31 ± 0.42	66.78 ± 4.26
2	Katan	5.44 ± 0.76	3.11 ± 1.1	1.32 ± 0.86	82.96 ± 3.72
3	Shalak	8.41 ± 1.12	7.61 ± 0.96	3.22 ± 1.22	115.05 ± 4.12
4	Khshni	9.82 ± 1.02	8.17 ± 1.62	4.1 ± 0.73	142.16± 4.86
5	Algharbia	11.42 ± 0.92	10.6 ± 0.71	3.9 ± 1.66	132.7 ± 3.62
6	Hmri	9.75 ± 0.66	11.42 ± 2.3	3.6 ± 0.92	161 ± 4.17
7	Carp	15.22 ± 2.61	18.62 ± 1.72	6.32 ± 2.47	155.05 ± 3.72
8	Jerry	17.82 ± 3.71	16.69 ± 2.82	5.57 ± 1.96	102.76 ± 2.61
9	Shbut	4.33 ± 1.42	9.42 ± 3.81	2.62 ± 0.42	78.62 ± 3.41
Average ± σ		9.84 ± 4.45	9.78 ± 5.42	3.66 ± 1.56	115.23 ± 34.6
Range		4.33 – 17.82	2.42 – 18.62	1.32 – 6.32	66.78 - 161

Table 2. Results of radiometric analysis for fish samples collected from Al-Hamar marsh.

No.	Fish type (local name in Iraq)	Radioactivity levels (Bq/kg ± σ)			
		^{238}U	^{232}Th	^{137}Cs	^{40}K
1	Al-buni	8.41 ± 1.42	6.19 ± 2.21	4.11 ± 1.21	82.51 ± 4.6
2	Shalak	7.86 ± 0.86	5.7 ± 0.67	3.16 ± 0.92	125.2 ± 4.71
3	Khshni	13.22 ± 1.67	7.42 ± 2.52	5.2 ± 1.48	139.61 ± 5.61
4	Algharbia	14.22 ± 0.86	15.12 ± 1.72	4.3 ± 2.2	164.67 ± 3.25
5	Hmri	10.21 ± 3.41	16.42 ± 2.11	5.2 ± 1.79	164.54 ± 1.12
6	Jerry	18.49 ± 2.73	15.74 ± 4.22	5.41 ± 2.21	145.5 ± 4.33
7	Carp	20.42 ± 3.45	19.1 ± 1.96	6.96 ± 2.96	105.42 ± 3.15
Average ± σ		13.26 ± 4.85	12.24 ± 5.59	4.9 ± 1.2	132.49 ± 30.4
Range		7.86 – 20.42	5.7 – 19.1	3.16 – 6.96	82.51 – 164.61

Table 3. Results of radiometric analysis for fish samples collected from Central marsh.

No.	Fish type (local name in Iraq)	Radioactivity levels (Bq/kg ± σ)			
		^{238}U	^{232}Th	^{137}Cs	^{40}K
1	Al-buni	11.92 ± 3.1	5.92 ± 1.4	4.02 ± 0.88	92.71 ± 3.41
2	Khshni	12.41 ± 1.46	9.62 ± 1.62	6.32 ± 1.55	168.61 ± 5.1
3	Hmri	14.62 ± 4.11	17.77 ± 2.42	7.22 ± 0.91	158.32 ± 3.22
4	Jerry	20.65 ± 1.46	19.32 ± 3.72	6.29 ± 1.11	152.62 ± 4.33
5	Carp	19.86 ± 2.42	19.4 ± 2.62	8.24 ± 3.16	144.7 ± 5.21
Average ± σ		15.89 ± 4.12	14.4 ± 6.23	6.41 ± 1.56	143.39 ± 29.64
Range		11.92 - 20.65	5.92 - 19.4	4.02 - 8.24	92.71 - 168.61

Table 4. Results of radiometric analysis for fish samples collected from Al-Masahab marsh.

No.	Fish type (local name in Iraq)	Radioactivity levels (Bq/kg ± σ)			
		^{238}U	^{232}Th	^{137}Cs	^{40}K
1	Khshni	14.62 ± 1.47	11.39 ± 2.04	7.82 ± 3.61	202.2 ± 4.32
2	Hmri	17.22 ± 2.32	19.1 ± 1.96	7.02 ± 0.82	231.42 ± 6.12
3	Jerry	21.71 ± 1.78	20.98 ± 2.49	8.67 ± 1.44	196.72 ± 2.71
4	Carp	19.66 ± 2.25	20.56 ± 1.81	9.42 ± 2.31	235.78 ± 3.21
Average ± σ		18.3 ± 3	18 ± 4.48	8.23 ± 1	216.53 ± 19.9
Range		14.62 - 14.62	11.39 - 20.98	7.02 - 9.42	196.72-235.78

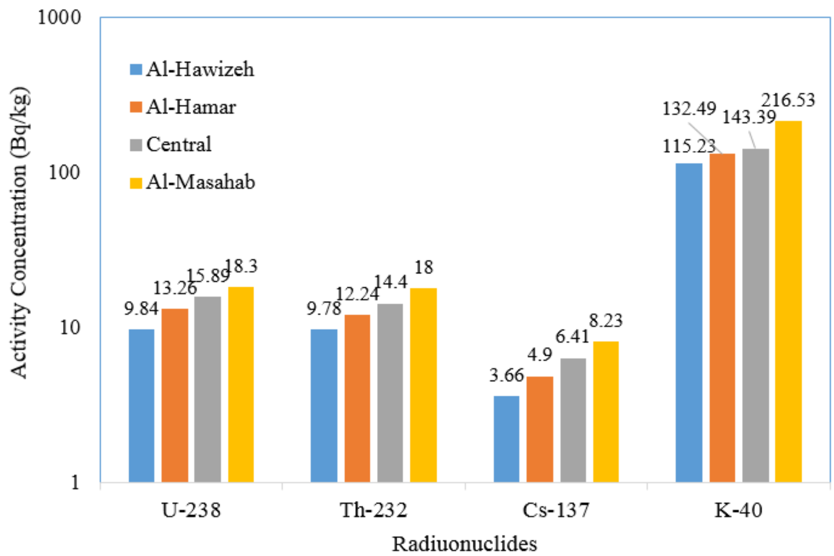

Fig.2.Mean values of radionuclides activity concentrations in investigated Iraqi Marshes

Table 5. Results of TDS measurements.

Measurement area	TDS (ppm)
Al-Hawizeh marsh	1320
Al-Hamar marsh	2386
Central marsh	2765
Al-Masahab marsh	3112

Table 6. Results of radiation dose and risk assessment.

Marsh	Radiation dose (Sv/y)	Radiation risk
Al-Hawizeh	2.76×10^{-5}	1×10^{-4}
Al-Hamar	3.43×10^{-5}	1.3×10^{-4}
Central	3.99×10^{-5}	1.5×10^{-4}
Al-Masahab	5.13×10^{-5}	2×10^{-4}

4 .Conclusions

The activity concentrations of natural and artificial radionuclides were studied in certain commercially important marshes biota (fish) from the Iraqi marshes (Al-Hawizeh, Al-Hamar, Central and Al-Masahab marshes). Through the analysis of fish samples using gamma-ray spectrometry system, activity concentrations were found to be ranged from 4.33 to 20.65 Bq/kg for ^{238}U, 2.42 to 20.98 Bq/kg for ^{232}Th, 1.32 to 9.42 Bq/kg for ^{137}Cs, and 66.78 to 235.78 Bq/kg for ^{40}K. The estimated radiation doses resulting from fish consumption vary widely depending on the concentrations of radioactive nuclides in the fish products, ranged from 2.76×10^{-5} Sv/y at Al-Hawizeh marsh, to 5.13×10^{-5} Sv/y at Al-Masahab marsh. For an annual fish consumption rate of 8 kg (Oxford University Press, 2013), ^{238}U, ^{232}Th, ^{137}Cs and ^{40}K would contribute a potential radiation risk range from 1×10^{-4} to 2×10^{-4}. These risk values are only a small fraction of the corresponding risk limit (10^{-3}) (Biswas *et al*, 2021; Asaduzzaman *et al*, 2015, Patra *et al*, 2013), indicating no radiological health hazard to the consumers.

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References

Asaduzzaman K, Khandaker M, Amin, Y., Mahat R (2015) Uptake and distribution of natural radioactivity in rice from soil in north and west part of peninsular Malaysia for the estimation of ingestion dose to man. Ann. Nucl. Energy 76, 85–93.

Amin R M, Ahmed F (2013) Estimation of annual effective dose to the adult Egyptian population due to natural radioactive elements in ingestion of spices. Adv. Appl. Sci. Res. 4, 350–354.

Biswas K P, Hossain S, Deb N, Bhuian A K M S, Gonçalves S C, Hossain S, Hossen M B (2021) Assessment of the Levels of Pollution and of Their Risks by Radioactivity and Trace Metals on Marine Edible Fish and Crustaceans at the Bay of Bengal (Chattogram, Bangladesh). Environments 8, 13.

Gorur F K, Keser R, Akçay N, Dizman S (2012) Radioactivity and heavy metal concentrations of some commercial fish species consumed in the Black Sea Region of Turkey. Chemosphere 87, 356–361.

Reported in Federal Guidance Report No. 13, Oak Ridge National Laboratory, Oak Ridge, TN, USA.

Patra A C, Mohapatra S, Sahoo S K, Lenka P, Dubey J S, Tripathi R M, Puranik V D (2013) Age-dependent dose and health risk due to intake of uranium in drinking water from Jaduguda, India. Radiat. Prot. Dosim. 155, 210–216.

Pulhani V, Dafauti S, Hegde A, Sharma R, Mishra U (2005) Uptake and distribution of natural radioactivity in wheat plants from soil. J. Environ. Radioact. 79, 331–346.

US EPA, Chapter 4: Risk-Based Preliminary Remediation Goals for Radioactive Contaminants, US. Environmental Protection Agency.

Wikipedia (2020), Mesopotamian Marshes, the free encyclopedia, https://en.wikipedia.org/wiki/Mesopotamian_Marshes.

ICRP (1994) Dose Coefficents for Intakes of Radionuclides by Workers; Publication 68, ICRP: Ottawa, ON, Canada.

IAEA (2014) Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, Safety Standards Series No. GSR Part 3, International Atomic Energy Agency, Vienna.

Kamal. K A, Baha A M (2011) Distribution of ^{137}Cs in the Surface Soil from Selected Areas in Iraq, Iraqi Bulletin of Geology and Mining 7(2), 1-8.

Khandaker M U, Asaduzzaman K, Nawi S M, Usman A R, Amin Y M, Daar E, Bradley D A, Ahmed H, Okhunov A A (2015) Assessment of radiation and heavy metals risk due to the dietary intake of marine fishes (Rastrelliger kanagurta) from the straits of Malacca. PLoS ONE 10, e0128790.

Oxford University Press (2013) Evaluation of radioactivity concentrations from the fukushima nuclear accident in fish products and associated risk to fish consumers, Radiation Protection Dosimetry 157(1), 1–5.

Pawel D, Leggett R W, Eckerman K F, Nelson C B (2007) Uncertainties in Cancer Risk Coefficients for Environmental Exposure to Radionuclides. An Uncertainty Analysis for Risk Coefficients