Investigation of the Natural Occurring Radioactive Material (NORM) in the cyprinus carpio fishes breeding in artificial lakes of Baghdad governorate

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Abstract

The steady consumption of fish led many researchers to study it preferences over other foods, especially for radioactivity content. The specific activity concentration (S.A) of natural occurring radioactive materials (NORM) have been measured for *Cyprinus carpio* fishes collected from several industrial fishes' lakes located in Baghdad governorate using gamma spectroscopy doped with high purity germanium coaxial detector (HPGe). Thirteen fishes' samples were collected from industrial lakes, three samples were collected from cages, and two samples were collected from Trigger River. The last two types of samples were collected in order to compare the results with it. The measured overall averages of S.A for Ra-226, Th-232, and K-40 were 58.9 Bq/kg, 14.1 Bq/kg, and 388.6 Bq/kg, respectively. Some radiation health hazard indices have been estimated, such as the annual effective ingestion dose for an adult member of the public due to the intake of radionuclide through ingestion of fish (H). The results of H showed that the cage fish is better than river fishes and lakes fishes. However, the results of S.A and H strongly suggested that the studied fish is safe to use for human consumption from radiological point of view.

Key words

Radioactive materials, artificial lake, fish, feed, sediment, water.

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التحري عن النظائر المشعة طبيعية المنشأ في أسماك الكارب التي تتربى في البحيرات الاصطناعية لمحافظة بغداد

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الخلاصة

ان الأستهلاك المضطرد للأسماك دفع بالعديد من الباحثين لدراسة افضليتهاعن بقية الأغذية، وخاصة من حيث المحتوى الأشعاعي. تم قياس تراكيز الفعالية الأشعاعية النوعية (S.A) لعينات اسماك كارب جُمعت من بحيرات الأسماك الصناعية لمحافظة بغداد بأستخدام منظومة مطياف كاما ذات كاشف الجرمانيوم المحوري عالي النقاوة. تم جمع ثلاثة عشر عينة من البحيرات الصناعية وثلاثة عينات جُمعت من الأقفاص الحديدية التي

توضع في النهر وعينتان من نهر دجلة. ان عينات الأقفاص الحديدية وعينات النهر جُمعت لغرض مقارنة نتائجها مع نتائج عينات البحيرات. ان نتائج المعدلات المُقاسة للراديوم-226 والثوريوم-232 والبوتاسيوم-40 هي 58.9 بكرل/كغم و 14.1 بكرل/كغم و 388.6 بكرل/كغم، على التوالي. لقد تم حساب بعض معاملات الخطورة الأشعاعية مثل (H) الجرعة الفعالة السنوية نتيجة استهلاك السمك بالنسبة للناس. ان نتائج H اوضحت بأن اسماك الأقفاص الحديدية افضل من النهرية والتي هي افضل من أسماك البحيرات. ومن نتائج S.A و H يمكن ان نقترح وبشدة ان عينات الأسماك التي تم دراستها أمنة للأستخدام البشري من وجهة نظر أشعاعية.

Introduction

Fish represents the extreme consumers in the global food system [1] and also has good ability to accumulate the highest concentrations of the natural and industrial radioisotopes more than other water systems such as water and sediments [2]. In addition to the organic material and the heavy elements present in the aquatic environment [3-4], radioisotopes enter to the aquatic food chains, especially fish, either directly through food or indirectly through gills [5]. However, one can call this pathway as internal intake of radioisotopes, which effected by the radioactivity concentration of water and provender (fish's feed). However, water system became contaminated with natural and industrial radioisotopes and it's signifies the important problem due to the cumulative usability even if concentrations few as they are non-biodegradable that cause chronic bad effects for various aquatic organisms [6, 7]. It can be exposed to the pollution of rivers with radioisotopes from various waste sources such as domestic, industrial, mining activities and agricultural activities as an addition of agricultural fertilizers, which affect the ecological balance in the water system [8].

The accumulation of Ra-226,Th-232 and K-40 in the bodies of fish affected by various factors such as pH, water hardness and the level of contamination in the water in addition to age and physiological status of fish [9]. Furthermore, the industrial and household wastes also contain heavy metals and hydrocarbon materials that accumulate in aquatic food chains, which can, like the effects of radiation, cause acute and chronic damage in fish communities and reduced their growth and reproduction. The composition of food chains in water system is complex compared with land where a small contamination block in the aquatic environment may be occurred noticeable changes making it more sensitive to pollution [2]. However, there are several researchers investigated the radiological isotopes in fishes' samples around the world [10-13].

The produced fish in artificial lakes was significantly increased especially in the central and southern governorates in Iraq. This is due to the drought most of the Iraqi marshes in southern Iraq, which were fed large amounts of fish, as well as, the ease of produced fish in lakes make it a bumper profit source for breeders. Cyprinus carpio is the most common used fishes in industrial lakes.

To determine the suitability for human consumption from radiological point of view, in this research, the concentration of naturally occurring radioactive materials (NORM) will measure in Cyprinus carpio fishes that breeder and producer in Baghdad governorate in Iraq.

Experimental part

a) Sample collection

Cyprinus carpio fishes' samples were collected from eighteen artificial fishes' lakes located at Baghdad city. There are two locations represents Trigger River and three locations represent cages and these locations were chosen in order to comparing the results with those obtained from lakes. Cages represents an iron perforated box with allowed only the river water to pass.

The longitude and latitude of the lakes and areas that fishes were taken illustrated in Table 1.

Table 1: Longitude and latitude of artificial fishes' lakes of Baghdad city with code for each sample.

	Lake name	longitude	Latitude	Fish code
1	Teremia	44°14′54. 72"	33°38'57.64"	F1
2	Madan / Dir'iya - **Cage**	44°37'47.06"	33° 5'19.02"	F2
3	Madan / Alkhanash	44°38'29.71"	33° 3'39.90"	F3
4	Madan/Bowie - **Cage**	44°33'18.92"	33° 9'3.27"	F4
5	Doraa / Arab Jabour	44°27'26.28"	33°11'55.76"	F5
6	Doraa/ Hor Rajab - **Cage**	44°23'51.11"	33°10'53.46"	F6
7	Madan - **River**	44°34'6.95"	33° 5'59.22"	F7
8	Yusufiyah1	44°14'46.13"	33° 4'11.11"	F8
9	Yusufiyah 2	44°14'57.21"	33°4′5.51″	F9
10	Taji 1	44°17'44.22"	33°32'32.54"	F10
11	Taji 2 – **River**	44°17'44.22"	33°32'32.54"	F11
12	Radwaniyah 1	44°14'54.14"	33°11'46.05"	F12
13	Radwaniyah 1	44°14'54.14"	33°11'46.05"	F13
14	Essaouira 1	44°43'19.99"	32°57'10.55"	F14
15	Essaouira 2	44°43'6.33"	32°57'6.19"	F15
16	Madan/Tuwaitha village	44°29'9.29"	33°11'15.03"	F16
17	Yusufiyah / Project	44° 9'59.89"	33° 2'50.94"	F17
18	Radwaniyah /makasab	44°14'25.28"	33°14'5.63"	F18

b) Sample preparation

Three different not dead samples fishes (from each lake) were collected with weight ranged from 750 to 1800 g and length varied from 25 to 50 cm. Samples have been dried by placing each sample under sun light for three weeks to drying it. Then, the dried samples were pulverized into a fine powder and passed through a standard 1 mm mesh size. The homogenized samples were filled into 1 L Marinelli beakers to measure the specific radioactivity by gamma spectroscopy doped with high purity germanium coaxial detector (HPGe). All samples were weighed using a fine balance with ± 0.01g error. For all samples, 1kg of sample mass was used and stored for at least one month prior to measurements in order to attain radioactive secular equilibrium between ^{226}Ra and ^{228}Ac and their short-lived progeny. HPGe that used in this work, is one of the semiconducting detectors, type p, made from Canberra Company. It contains crystal of 7500SL model with 62mm diameter and 60 mm length. This detector works by running voltage at 4500 V with efficiency ≥ 40% and energy resolution ≤ 1.8 keV for the energy line 1.33 MeV for ^{60}Co radioisotope. This type of detector cooled to - 196 ^{0}C when operating by liquid nitrogen. The detector was surrounded by a wall of lead with a thickness of 10 cm to reduce the background radiation. It is coated from the inside with a thin layer of cadmium with thickness 1.6 mm and thin layer of copper with 0.4mm thickness to attenuation X-ray that result from interaction of gamma rays with a lead material.

Results and discussion

The specific activity concentration (S.A) of potassium – 40 (K-40), radium – 226 (Ra-226), and thorium – 232 (Th-232) have been measured for the investigated fishes' samples. In addition, the internal hazard index (H_{int}), the gamma representative index ($I_{\gamma r}$), the radium equivalent hazard index (Ra_{eq}) and the annual effective ingestion dose for an adult member of the public due to the intake of radionuclide through ingestion of fish (H) [14] were calculated. The overall results of the radiological investigations for fishes' samples were illustrated in Table 2. From this table, S.A for Ra-226 ranged from 38.7 Bq/kg in F4 sample to 95.6 Bq/kg in F8 with an overall average value about 58.9 Bq/kg. Whereas, the ranged values of Th-232 were from 10.0 in F4 sample to 18.1 Bq/kg in F5 sample, with an overall average about 14.1 Bq/kg. In addition, the minimum value of K-40 was 179.7 Bq/kg in F14 and the maximum value was 793.1 Bq/kg detected in F5 sample, while the overall average value for all measured samples was 388.6 Bq/kg.

The hazard indices; Ra_{eq}, $I_{\gamma r}$, H_{in}, and H were calculated, which differ in importunity according to health effects on human consumers. H, which is the annual effective ingestion dose for an adult member of the public due to the intake of radionuclide through ingestion of fish, is the important hazard index, while the others were calculated to ensure from the radiation effects on the consumers. However, the results of these parameters, also, showed in Table 2. The minimum value of H was 22.3 μSv/y that measured in F4 sample and the maximum value was 51.7 μSv/y in F5 sample, whereas the overall average value was 33.0 μSv/y.

Furthermore and in addition to Table 2. show the specific activity concentrations of Ra-226, Th-232, and K-40, the internal hazard index (H_{int}), the gamma representative index ($I_{\gamma r}$), the radium equivalent hazard index (Ra_{eq}), and the annual effective ingestion dose for an adult member of the public due to the intake of radionuclide through ingestion of fish (H), Figs. 1 and 2 illustrat S.A for Ra-226 and Th-232, and for K-40, as a function of the investigated locations, respectively. Fig.3 shows the calculated results of H for all investigated fish samples.

Furthermore, the general view in Fig.3 gave us the behavior of the effected H on the consumers according to the type of fish's environment. Consequently, the cages represent the best environment to produce fishes and the revers' fish is the second best environment. This behavior can be attributed to the continuous changed of waters, which provide the requested oxygen for fish breathing. Additionally, the cages' fishes are best than revers' fishes because of the feeding of these fishes, which is in the cages depend on delivered imported provender while in revers depend on the locally natural provender.

Table 2: The overall results of radiological tests for studied fish's samples.

Sample's Code	S.A ^{226}Ra (Bq/kg)	S.A ^{232}Th (Bq/kg)	S.A ^{40}K (Bq/kg)	H_{int}	Iγr	Ra_{eq} (Bq/kg)	H (μSv/y)
F1	67.3	13.8	403.5	0.50	0.86	118.1	36.6
F2	48.1	12.4	395.5	0.39	0.71	96.3	28.0
F3	53.8	13.9	343.3	0.42	0.73	100.1	30.4
F4	38.7	10.0	298.7	0.31	0.56	76.0	22.3
F5	91.2	18.1	793.1	0.73	1.32	178.2	51.7
F6	44.2	11.4	339.6	0.35	0.64	86.7	25.5
F7	68.3	17.0	353.5	0.51	0.86	119.8	37.6
F8	95.6	16.3	432.0	0.67	1.09	152.2	49.5
F9	74.6	17.9	569.1	0.59	1.06	144.0	42.5
F10	55.5	14.3	398.2	0.44	0.78	106.6	31.7
F11	47.9	12.4	302.0	0.37	0.64	88.9	27.0
F12	57.7	14.9	354.3	0.44	0.77	106.3	32.4
F13	51.6	13.4	411.9	0.42	0.75	102.5	29.9
F14	43.7	11.5	179.7	0.32	0.53	74.0	23.8
F15	47.2	12.3	227.2	0.35	0.59	82.3	26.0
F16	61.3	15.2	404.7	0.47	0.83	114.2	34.5
F17	55.9	14.0	391.5	0.44	0.77	106.1	31.7
F18	57.1	14.7	397.7	0.45	0.79	108.7	32.5
Overall average	**58.9**	**14.1**	**388.6**	**0.45**	**0.79**	**108.9**	**33.0**

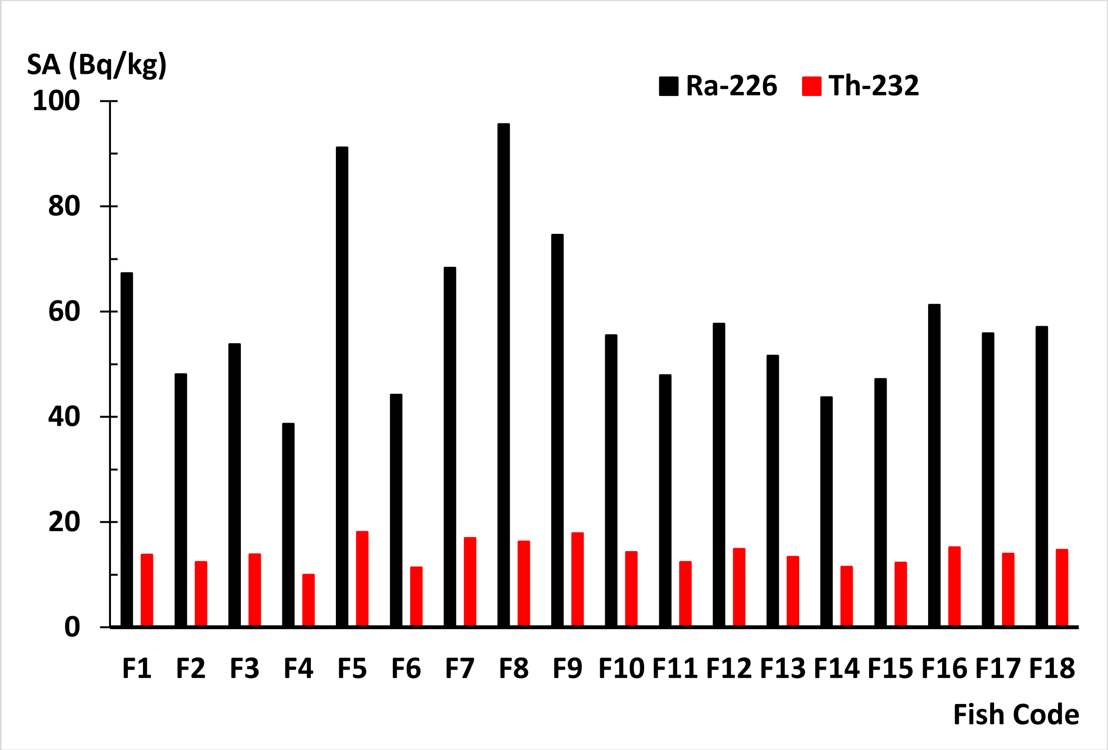

Fig. 1: The radiological specific activity (SA) of Ra-226 and Th-232 isotopes as a function of fish sample location.

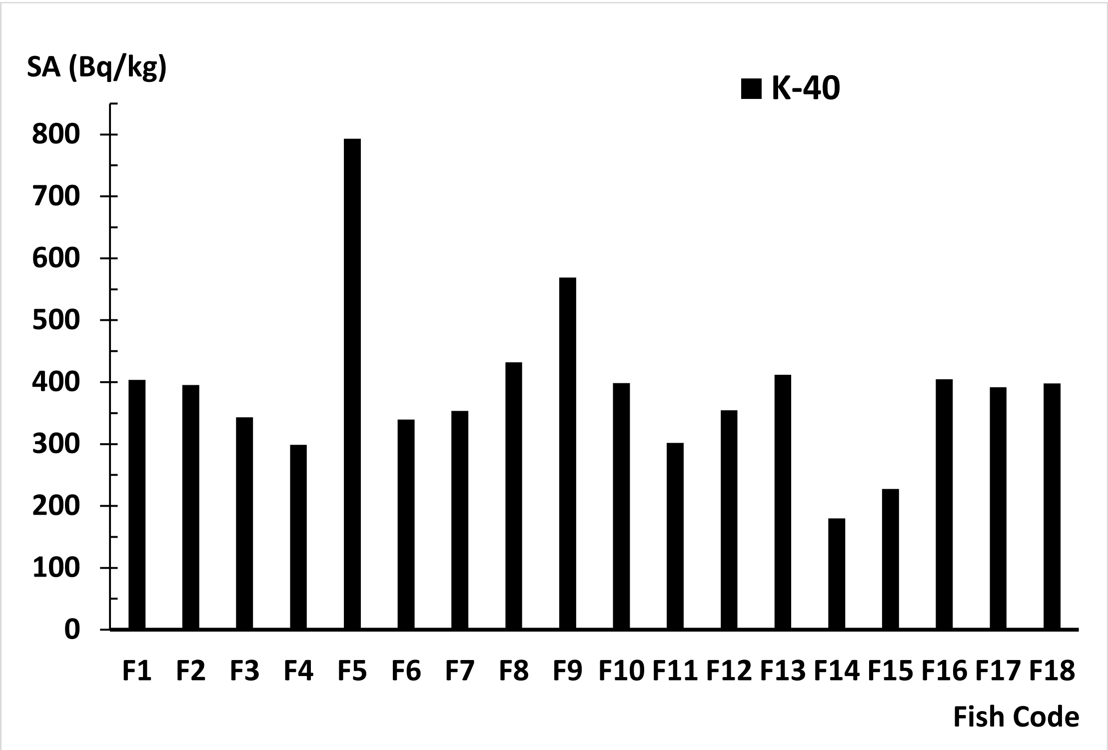

Fig. 2: The radiological specific activity (SA) of K-40 isotope as a function of fish sample location.

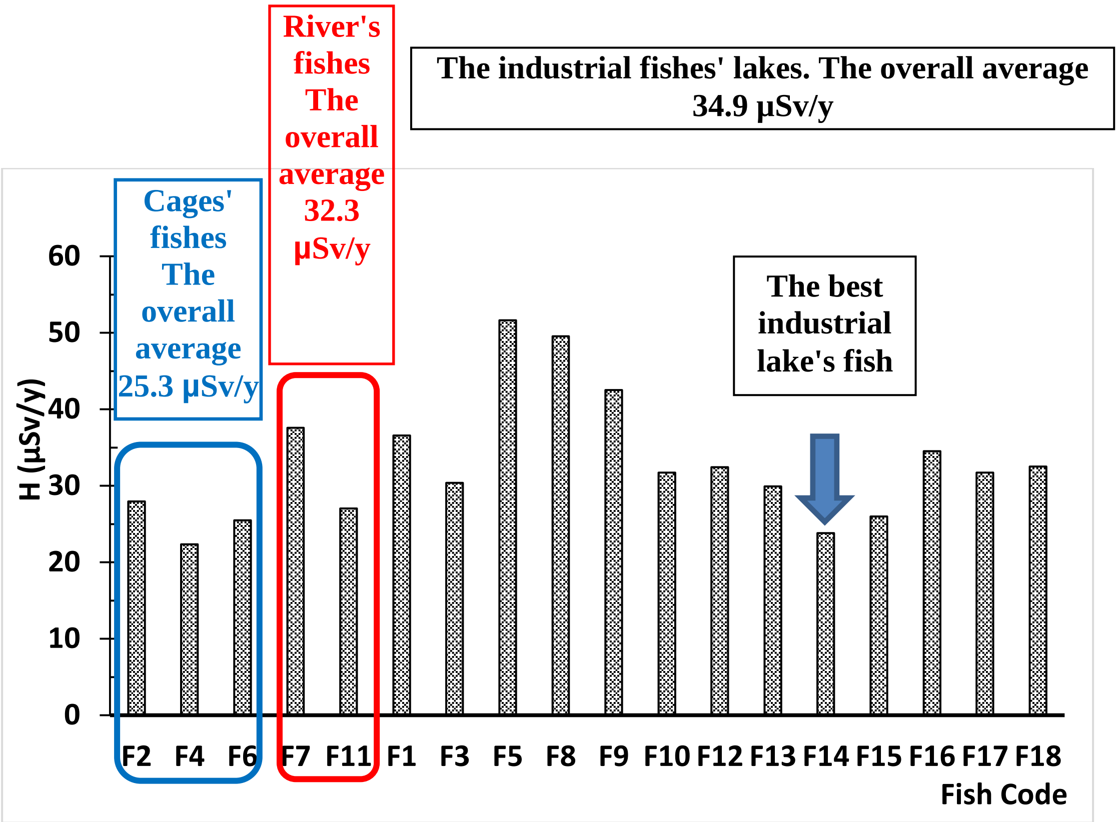

Fig. 3: H calculations values for fish samples.

However, the best consuming fishes produced in artificial lakes according to H is the fishes produced in "Essaouira 1" farms, i.e. samples F14. This can attribute to the following reasons؛

1) The farmers used newly automatic machines to provide the lakes with important and required oxygen.
2) They followed the instructions of the fishes' specialists.
3) They used locally provender mixed and prepared according to the advice of the specialists.

In order to establish a real comparison, one must depend on a study or works used same conditions, such as the detected techniques, which are HPGe gamma spectroscopies used in our measurements. So, when reviewed the available works, we found the works of reference [10] used the same our procedure. Therefore, this reference [10] was used to compare our results with it. Table 3 shows the results of reference [10] that measured Ra-226, Th-232, and K-40 for river and marine fishes in Nigeria. In general, all the results of this reference are higher than our results with different percentage ratios. From health effects point of view, the hazard indices were estimated for the results of reference [10], and the calculated H of this reference is roughly about 13.8 % higher than our result. This indicates that the produced fishes in Baghdad governorate lakes are safe for human consuming.

Table 3: The results of radiological tests for Fresh water fishes (F) and Marine water fishes (M) taken from reference [11]. This study achieved in Nigeria and illustrated here in order to compare our results with it.

Fish type	Sample's Code	S.A K-40 (Bq/kg)	S.A Ra-226 (Bq/kg)	S.A Th-232 (Bq/kg)	Hint	Iγr	Ra_{eq} (Bq/kg)	H (μSv/y)
Gymnarchusniloticus	F1	792.00	38.60	42.8	0.539	1.213	160.79	37.70
Parachnnaobscura	F2	523.00	32.20	84.4	0.609	1.407	193.16	46.24
Heterotisniloticus	F3	627.00	32.90	64.9	0.559	1.286	173.99	41.07
Clariasanguillaries	F4	607.00	21.40	63	0.485	1.177	158.23	35.42
Oreochromisniloticus	F5	462.00	25.60	52.4	0.437	1.003	136.11	32.34
Average		**602.20**	**30.14**	**61.5**	**0.526**	**1.217**	**164.45**	**38.55**
Cynoglossussenegalensis	M1	791.00	49.70	96.7	0.806	1.826	248.89	60.14
Arius heudolotis	M2	688.00	23.00	44	0.437	1.052	138.90	30.58
Dasyatis margarita	M3	753.00	40.10	53.3	0.579	1.302	174.30	41.43
Chrysithctysnigrodigitatus	M4	723.00	27.80	32.1	0.425	0.988	129.37	28.99
Peanusmonodon	M5	525.00	35.30	31.9	0.423	0.904	121.34	30.24
Average		**696.00**	**35.18**	**51.6**	**0.534**	**1.215**	**162.56**	**38.28**

Conclusions

From the obtained results, one can conclude that the annual effective ingestion dose for an adult member of the public due to the intake of radionuclide through ingestion of fish (H) of the cages' fishes better than others, and the sample F14 (the lake's fish from "Essaouira 1" farms) has a very low value. This can be attributed to the ventilation system that used in this lake. All the obtained results showed that the produced fishes from all lakes were safer to use by Iraqi consumers.

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