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ORIGINAL ARTICLE

Evaluation of Cs-137 and natural radionuclides on different marine biota (crustacean and fishes) along Beheira governorate Coast-Egypt: RESRAD biota

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ABSTRACT

Purpose: This work will focused on the environmental and radio-ecological impacts occurred on an Egyptian coastal region, based on the radiochemical measurement of ^{238}U, ^{137}Cs, ^{232}Th, ^{40}K. The novelty of the study was cleared by the using of new technique showing the integration of two biological RESRAD models, lead to a probabilistic estimation of the radionuclides bioaccumulation in different consumed marine organisms and determination the probability of human cancer risk at different ages.

Material and methods: The 20 water samples were collected and mounted into clean containers, and their decay products, were measured in Bq.L^{-1}, using different quality assurance tools. The study will used different statistical analysis and different RESRAD modeling codes were used in the study to predict the degree of environmental and radio-ecological impacts at the studied area, this will be helpful in order to define the impacts resulted from the transferring and accumulation of different radionuclides.

Results: showed that the highest human dose conversion factor values of (5, 10, 15, with adult ages) were measured in Th-232 (mrem/pCi) while the lowest ingestion conversion factors values were observed in artificial ^{137}Cs. On the other hand the highest values of external risk factor in case of (5, 10, 15 with adult age) were observed in artificial Cs-137(mrem/pCi), while the lowest value of external risk factor with the same ages were observed in U-238. This will lead to continual monitoring of artificial Cs-137 in different marine coastal regions. The arrangement of the bioaccumulation value (BIV) in Bq.kg^{-1} which being calculated by using RESRAD-Biota in case of crustacean animals will be as follow: U-238 > Th-232 > Cs-137, while the arrangement of BIV in case of fish animals will be: Cs-137 > U-232 > Th-232. On the other hand the arrangement of Internal Dose Conversion factors in case of crustacean animals will be: U-238 > Th-232 > Cs-137. While the arrangement of Internal Dose Conversion factors in case of fish animals will be: Cs-137> Th-232 > U-238.

Conclusion: RESRAD code's results showed that the arrangement of the bioaccumulation and Dose Conversion factors were depend on the type of marine living organism. RESRAD code also showed that there are increments of the calculated external risk factor values which resulted from the adult than all the infants (5,10 and 15 ages) ages this may be related to the continuous replacement of new human's body cells during the growth stages. The study results showed that, environmental bioaccumulation impacts of the artificial Cs-137 were very effective in both marine living organisms and human as this will support the relation between the ingestion Cs-137 in the body(inside the soft tissues), and the probability of the human cancer risk. On the other hand, study results showed the importance of using RESRAD BIOA code for the EIA's ecological and radiological studies which should be done for any future industrial coastal .projects.

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Bioaccumulation factor; risk factor; radionuclides; crustacean; fishes; RESRAD-BIOTA

Introduction

The environmental and radiochemical risk assessment in coastal areas is becoming a very important tool to detect any global threat to sustainable health and marine ecological, especially in coastal places with high background radiation, such as Behira coastal area which is located on the Egyptian Mediterranean coastal region based on its high radiation background, (black sands) and being protected by a sea wall located at nearly 20 to 35meters development this complied with which being reported by Muhammad (2013). The uptake process of radionuclides by different marine sediments, depends on many parameters such as, physical and chemical properties of the sediments. Many studies showed that the bioavailability of radionuclides being covered by the correlation between the radionuclides and their sedimentation showed by Fuller et al. (2015). Uranium has different health impacts on human body when being ingested, where it was being classified as chemical carcinogen that the increasing of cancer risk is influenced by the increasing of the internal exposure of radioactivity, this is due to accumulation of more insoluble compounds in lung during inhalation process, as observed by Venturi (2021),

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which also recorded that thorium which is natural occurring radioactive element with very long half live as in case of thorium-232 and thorium-230, where their low specific activity means that thorium-232 and thorium-230 are not highly radioactive. It was observed that risk coefficient of thorium-230 is similar to thorium-232. Radioactive artificial Cs (^{137}Cs and ^{134}Cs) which is a basically absorbed by living organisms, Cs-137 has a physical half life of 30.2 years, a high fission yield, and a high bioavailability due to its physiological similarity to potassium which cause the main factor in its movement through aquatic and terrestrial food chains (Crustaceans and Fish) where it concentrate in soft tissues such as edible, skeletal muscle and its bioaccumulation will be in high tropic level consumers, including humans (Mavrokefalou et al. 2017), reported that Cs^{137} is very hazardous isotopes, as the beta emissions of Cs^{137} are dangerous during ingestion, where Cs^{137} which can enter the body with different pathways as it can be taken into the body by; eating food, drinking water, or breathing air and behaves in radio-biochemical reactions similar to potassium, this leads Cs^{137} to distribute uniformly throughout the body, where all the ingested Cs-137, is absorbed into the bloodstream through the intestines (Petrovic et al. 2018), showed that in the last 15 years, relevant software tools been developed, such as the ERICA, Assessment tool and RESRAD-BIOTA code that provide dose estimations for organisms in several environments, based on ecosystem- specific ecological interactions that affect radionuclides distribution in the environment. These tools provide adequate methodologies for the reasonable and conservative estimation of dose rate to non-human organisms, especially when dose estimation is required for regulatory purposes. Petrovic et al. (2018) reported that, RESRAD-BIOTA code is considered one of these simulating tools which had advanced analysis capabilities in residual radioactivity determination. The advantages of using RESRAD-BIOTA code based on the calculations of the internal dose and external doses which are very advantageous parameters in the determination of residual radioactivity of non-human marine biota microorganisms. All the previous calculated internal and external doses parameters supported by using of RESRAD-BIOTA code as recommended Biological or Biota Contamination Guidelines (BCG) for each medium, as the total sum of used fractions shall not exceed 1.0. RESRAD-BIOTA code is being widely used for both aquatic and terrestrial system evaluations, as it was observed that if the sum of the summed ratios between the radionuclide concentrations in environmental media and the radionuclide specific BCGs is less than 1.0, the dose to an aquatic or terrestrial receptor is below the biota dose limit, and it will be passed to the general screening evaluation. While when the sum is greater than 1.0, there will be further investigation should be required Many studies reported that the risk coefficient for ingestion actually is lower than the risk coefficient for inhalation which is complied with RESRAD Code and U.S. Department of Energy (2019). Transfer to sediment depends on whether the radionuclide behaves as a conservative (non-reactive-remains dissolved in the water column, or non-conservative which is reactive –has a strong affinity for suspended particles and sediment as reported by Bird (2012).

Material and methods

Site description

Field study was done on Beheira coastal line where it is characterized by its length which is of about 55 km and its location where is between Latitudes 31° 26⁻ N and 31° 29⁻ N and Longitudes 30° 21⁻ E and 30° 28⁻ E as being showed in Figure 1. It was noticed that the coastline from Beheira outpouring to Damietta estuary is bounded by two heads at its east and west extremities where is divided into two bays by means of a protruding head at Baltim. The Rashid headland extends in the sea for about 7.5 km with NNW trend, where

Figure 1. Description of Beheira collection sites using GIS code.

the mouth (about 75 m wide) of Rashid branch deposits in the sea. Its width now is about 15 km, with gentle bend, and curvature. The waves are very active at its both sides and lead to effective erosion of the beach as observed by Muhammad (2013).

Aim of the study

Using the Dose Conversion Factor editor version 3.0 apart with RESRAD BIOTA version 1.8, will be considered as two supportive apporaches used in the determintion of different radiological risks factor in both human and non-human orgnismes. Basically the novalty of using of such two previous codes was cleared during the assissing the calculated dose conversion factors for different radionuclides and their related morboidity factor of different human ages (5,10,15 and Adult) RESRAD code complyied with the RESRAD Code and U.S. Department of Energy (2019). The proposed tools were also effective for the determination of the transfer factor of different radionuclides through different marine living organismes. As being showed on the Eq. (1): the dose/exposure ratio,

$$\mathrm{DCF(i)} \ = \mathrm{H/E(i)} \tag{1}$$

Where H is the effective dose equivalent as H is incurred in an individual of exposure from intake by ingestion of a quantity E(i). Ingestion dose conversion factors depend on the chemical form, which determines the fraction f1 of a radionuclide entering the gastrointestinal (GI) tract that reaches body fluids as reported by RESRAD Code and U.S. Department of Energy (2019).

Sampling process

Sampling process was conducted during June 2020. Twenty water samples were collected of twenty different sites at the inshore of the Egyptian Beheira coast being showed in Figure 1. These samples were taken from the beach subsurface (1-2 m) reported by (IAEA 2019). The concentrations of the natural occurring radionuclieds and the artificial ^{137}Cs were being measured. The samples were mounted into clean containers, and then the activity concentrations of and their decay products, were measured in Bq/L, using gamma-ray spectrometer based on high-purity germanium (HPGe) detector of 40% relative efficiency, 1.92 keV resolution for 1332 keV gamma-ray line of ^{60}Co.

Quality control and method validation

Validation steps

Calibration using reference standards or reference materials, then comparison of results achieved with other methods, inter-laboratory comparisons; assessment of uncertainty of the results based on scientific understanding of the theoretical principles of methods and practical experience. For quality assurance and validation purpose, blank samples were prepared in same manner as corresponding samples, and measured for background estimations, and detection of any radioactive contamination. Reference water samples were samples were determined using the same analysis and measurement, and compared against their certified values to test the closeness of the measured samples to its reference values. The minimum detectable activity (MDA) of the analyzed radionuclides at a confidence level of 95% was calculated for each energy line in the background spectrum, as the detector was coupled with multi-channel analyzer (16 k channels) and GENIE 2000 software. Point sources of ^{137}Cs (661.6 keV) and ^{60}Co (1172 and 1332.3 keV) were used for the spectrometer energy calibration. The minimum acquisition time was 22 h to reduce the statistical as well as area calculation errors. The IAEA reference materials RGU-1 was used for the spectrometer efficiency. Calibration was done in the same geometry as that of the sample measurement reported by ERL (2020). The activity concentrations of ^{238}U, ^{232}Th, and ^{40}K were determined using their most intensive gamma-transitions and/or their progenies. The Minimum Detectable Activity (MDA), determined for the detection system and radiochemical procedures adopted in this study as presented by Eq. (2) complied with Friedlander et al. (2005).

$$\mathbf{MDA} = \mathbf{2.71} + \mathbf{3.29}Np\sqrt{}k * V * t[\mathbf{Bq/cpm}] \tag{2}$$

Where: N_p is the background (CPM), k is the calibration factor ($CPM.Bq^{-1}$) and m is the mass of the sample (kg). The calibration factor was defined according to Eq. (3) reported by ERL (2020).

$$k = Nt * A \tag{3}$$

Where: t is the counting time of the sample (s), A is the activity of the standard (Bq), and N is the number of counts from the standard sample. The MDA was 0.17 mBq for samples with counting time 1600-minute and chemical recovery ranged between 75% – 80%, reported by Friedlander et al. (2005).

GIS tool

Over the last year GIS tool apart from being used for the analysis and graphical representation of environmental pollution (chemical, thermal pollution in water, and air media) also has been used for the analysis of radioactive pollution distribution and impact on the environment, it has been an integral tool for studying radioactivity in the environment and helping with radiation risk assessment in the environment, whereas, it is also used for decision making. The study used GIS tool to manupiuale with the sampling sites data, to provide the study with different GIS maps used as helpful tool in decision making and environmental impact assessment processes.

Reference organisms

Using the reference organisms as a basis to develop an environmental radiochemical interaction, and are considered ecologically reprehensive of a specified group of plants or animals with biological characteristics amenable to study. Non-human biota in radiological risk assessment is typically evaluated using reference organisms (ROs) or Reference Animals and Plants (RAPs), for all exposure situations. However, it still remains open whether the use of an increased number of species would improve the stability to demonstrate protectiveness of the environment, to support the development of robust, applicable ecological benchmark values for environmental radioprotection it is necessary to review and identify research needs for radiological studies in the selected reference organisms which is observed by ERL (2020). The crustacean animals were selected as reference organisms in the study, as they bear different parameters such as temperature and salinity of marine water (Behira region).

RESRAD BIOTA code

Using of RESRAD BIOTA modeling version will help to conduct detailed ecological risk assessments of radiation., using internal dose conversion factor and Bioaccumulation value (BIV) to provide estimating of organism tissue concentration. The bioaccumulation (BIV) corresponding to organisms which are more representative of the expected food sources for the riparian selected to use in the selected site complied with Sotiropoulou (2017). The Biota Concentration Guideline (BCG) in RESRAD-Biota is designed to be the maximum radioactivity concentration limit to guarantee the safety of biota. The BCGs were estimated and assuming the exposure for aquatic organisms and sediment is external exposure. Maximum media activity concentrations are compared to biota concentration guidelines (BCG). Determination of BCG (Biota Concentration Guideline) is calculated by following Eq. (4) as reported with Sotiropoulou (2017).

$$\mathrm{BCG}(\mathrm{Bq.Kg}^{-1}) = \mathrm{Dose\ Limit}/\mathrm{Internal} + \mathrm{External\ Dose} \tag{4}$$

Where crustacean and fishes animals were selected as input data, with different sizes as; (0.005 Kg) in case of crustacean animal where using (1Kg) in case of fish animal. On the other hand the measured natural radioactivity, of Th-232, U-238 and artificial Cs-137 will be used as a input data in the determination of bioaccumulation factor as reported by RESRAD-BIOTA. 2004.

Using statistical analysis

Statistics is the cornersone in the interpretation of radiological measurements. A single measurement has an associated error, critical level, and detection level. Lower limit of detection or minimum detectable activity. Groups of measurements have means, standard deviations, many other parametric measures. Multiple groups of measurements can be compared by many methods to determine equivalency using hypothesis (t-test) (Adiene 2017). Different statistical analysis were being done in the study using different paramters such as Standard deviation, average mean, with t-test, using different correlations.

Results and discussion

Radioactivity results of studied areas

The behavior of radionuclides in aquatic ecosystems depends on the chemical characteristics of the radionuclide, the nature of the water body, and physical state of the radionuclide and chemical composition of the water. The purpose of using RESRAD is to evaluate radiological hazards to biota in support of site Environmental Management Systems (EMSs). In contrast a significance independent t-test value independent samples t-test used when comparing the means of precisely two groups (no more and no less (2.228E-14) was observed between the radioactivity of K-40 and U-238 as, $p < .05$), (if the p-value is less the significance level (0.05) rejection of the null hypothesis will be occurred) as this significance occurred with a negative correlation (−0.311). There was a significance independent t-test value (2.968E-14) observed between the radioactivity of K-40 and Th-232 as, $p < .05$), this significance occurred with a negative correlation (−0.335). On the other side there was a significance independent t-test value (1.52E-11) between the radioactivity of U-238 and Th-232 as, $p < .05$) this significance occurred with positive correlation (0.957). This due to the radioactivity of both uranium and thorium which are being occurring with low concentrations compared with K-40 radionuclide which is the most abundant natural occurring radionuclide in the earth crust as reported. These significance values are being discussed in Table 1 where the highest activity was 484.73 $\mathrm{Bq.L^{-1}}$ recorded in site (6) in the range of K-40 $\mathrm{Bq.L^{-1}}$, with mean average value (333.85) $\mathrm{Bq.L^{-1}}$, ranged from (227.05-484.73) $\mathrm{Bq.L^{-1}}$ and with STDEV.p (69.59554) and STDEV.s (71.40352), this was due to the nature of the sand sediments of a geological structure of marine rocks at this site, while the lowest mean average value was 227.05 $\mathrm{Bq.L^{-1}}$ found in site (14). It was observed that typical K-40 concentrations in living organisms are within about a factor of two of 0.1 $\mathrm{Bq.g^{-1}}$, which makes Potassium does not bio-accumulate. In case of using RESRAD-BIOTA code the determination of the bioaccumulation factor of K-40 is not a useful parameter, as the internal dose is fixed. Therefore, either K-40 data should be omitted, or if the external dose is of interest the value of BIV should be set to zero so that the internal dose from K-40 will not be included. In contrast the man made source Cs-137 highest concentration value was found at site (2) with concentration value (2.01) $\mathrm{Bq.L^{-1}}$, where being showed in Table 1 this result was due the presence of different industrial leakage like; phosphate industry which being found at this site, on the other hand the lowest value (0.54) $\mathrm{Bq.L^{-1}}$ was found at site (18), basically, all the measured activity of artificial Cs-137 were below the background radiation limits reported by Fegan et al. (2008).

Bioaccumulation results of marine (crustacean and fishes) animals

Table 2 and Figure 2 showed that the highest bioaccumulation factor (BIV) value of the crustacean marine animals in case of measured U-238 radionuclide, was recorded in site (9) with $2.01\mathrm{E}+3\ \mathrm{Bq.kg^{-1}}$ while the lowest BIV value

Table 1. Measuring the radioactivity concentrations in Bq.L^{-1} of U-238, Th-232,K-40 and Cs-137 along the different sites of the study area during June 2020.

Sample No	U 238	Uncertainty	Th 232	Uncertainty	K 40	Err	Cs 137	Uncertainty
1	15.83	0.5	12.11	0.33	369.77	15.33	0.84	0.15
2	8.19	0.51	7.7	0.4	300.65	7.54	2.01	0.84
3	13.8	0.33	13.17	0.32	348.7	10.06	0.69	0.15
4	9.68	0.27	10.95	0.28	368.7	9.25	ND	ND
5	12.39	0.29	9.36	0.29	350.95	9.16	0.94	0.16
6	8.77	0.28	6.95	0.25	484.73	8.52	ND	ND
7	11.14	0.27	7.83	0.26	380.41	8.75	1.21	0.17
8	24.75	0.44	32.47	0.5	255.43	7.78	ND	ND
9	26.38	0.54	34.8	0.58	297.21	5.91	ND	ND
10	7.11	0.28	5.05	0.25	366.35	7.01	ND	ND
11	11.74	0.33	12.01	0.35	406.04	7.43	ND	ND
12	8.57	0.37	7.66	0.33	304.91	6.13	1.62	0.24
13	7.31	0.23	9.15	0.32	441.56	7.58	0.88	0.12
14	14.4	0.34	12.4	0.34	227.05	3.92	ND	ND
15	13.89	0.33	14.13	0.37	256.71	3.84	1.94	0.19
16	14.34	0.34	15.26	0.37	265.41	4.86	1.73	0.15
17	10.04	0.38	10.13	0.32	256	4.79	ND	ND
18	10.41	0.42	6.68	0.37	405.65	5.95	0.54	0.08
19	4.46	0.26	3.35	0.3	243.41	5.32	1.14	0.11
20	6.99	0.37	4.93	0.27	347.39	10.38	0.69	0.066
Max	26.38		34.8		484.73		2.01	
Min	4.46		3.35		227.05		0.54	
Average	12.01		11.80		333.85		1.19	
STDEV.p	5.38213		7.92503		69.59554		0.49309	
STDEV.s	5.52195		8.13091		71.40352		0.51502	

Table 2. Calculation of BIV bioaccumulation factor of some selected radio-nuclides in the (crustacean &fish) of marine animals measured in (Bq.kg^{-1}) at different sites along the study area using RESRAD-Biota.

	Bioaccumulation factor BIV in marine crustacean animal Bq.kg^{-1}			Bioaccumulation factor BIV in marine fish Bq.kg^{-1}		
Sites no	U-238	Th-232	Cs-137	U-238	Th-232	Cs-137
1	1.60E + 03	7.00E + 01	1.20E-04	3.98E-02	3.54E-02	3.38E + 00
2	1.510E + 03	7.00E + 01	2.10E-04	3.78E-02	3.34E-02	4.38E + 00
3	1.20E + 03	6.90E + 01	1.90E-04	3.68E-02	3.14E-02	3.28E + 00
4	1.40E + 03	8.00E + 01	*ND	3.98E-02	3.54E-02	*ND
5	1.30E + 03	8.00E + 01	2.30E-04	3.78E-02	3.84E-02	3.38E + 00
6	1.20E + 03	6.9.00E + 01	*ND	3.8E-02	3.04E-02	*ND
7	1.20E + 03	8.00E + 01	2.10E-04	398E-02	3.54E-02	3.38E + 00
8	1.10E + 03	8.00E + 01	*ND	3.98E-02	3.54E-02	*ND
9	2.01E + 03	9.00E + 01	*ND	4.98E-02	4.54E-02	*ND
10	1.120E + 03	6.00E + 01	*ND	3.98E-02	3.54E-02	*ND
11	1.03E + 03	8.00E + 01	*ND	3.98E-02	3.34E-02	*ND
12	1.50E + 03	7.00E + 01	2.20E-04	4.018E-02	3.84E-02	3.38E + 00
13	1.70E + 03	8.00E + 01	1.90E-04	3.98E-02	3.94E-02	3.9E + 00
14	1.03E + 03	4.040E + 01	*ND	3.48E-02	3.54E-02	*ND
15	1.90E + 03	8.00E + 01	2.20E-04	3.88E-02	3.54E-02	3.06E + 00
16	1.30E + 03	5.00E + 01	1.20E-04	3.18E-02	3.14E-02	3.08E + 00
17	1.20E + 03	7.00E + 01	*ND	3.98E-02	3.54E-02	*ND
18	1.00E + 03	6.00E + 01	2.01E-04	3.08E-02	3.04E-02	3.38E + 00
19	1.00E + 03	7.00E + 01	2.20E-04	3.98E-02	3.4E-02	3. 8E + 00
20	1.00E + 03	5.00E + 01	1.30E-04	3.98E-02	3.4E-02	3.48E + 00

*ND: Non Detected.

1.03E + 3 Bq.kg^{-1} was found at site (14). In contrast the highest bioaccumulation value in case of Th-232 in crustacean animals was (9.00E + 1) Bq.kg^{-1}, was found in site (9), where its lowest BIV value was (4.04E + 1) Bq.kg^{-1}, recorded in site (14) as being showed at Table 2 and Figure 2. In case of Th-232, Table 2 and Figure 2 showed that the highest BIV was (4.54E-02) Bq.kg^{-1} found at site (9), while it's the lowest BIV was (3.04E-02) Bq.kg^{-1} at site (18). In case of artificial Cs-137, Table 2 and Figure 2 showed that the highest BIV value was (4.38E + 00) Bq.kg^{-1} at site (2) while its lowest BIV value was (3.06E + 00) Bq.kg^{-1} kg at site (16). A significance independent t-test value (2.593E-14) was occurred between natural U-238 bioaccumulation factor of crustacean and fish marine animal as, $p < .05$. This significance value was being observed due to the chemical selectivity of uranium inside the crustacean and fish tissues based on the conductivity and temperature of Bahira coastal region. Another significance independent t-test value (0.000284) between artificial Cs-137 bioaccumulation factor of crustacean and fish marine animal was reported, as $p < .05$, this significance value being explained due to the chemical selectivity of Cs-137 inside the crustacean and fish tissues which resemble the chemical selectivity of stable potassium element on the selected coastal region (Zhao et al. 2001). As the result of the previous results, the arrangement of BIV of different radio-nuclides in the crustacean animals will be as follow: BIV of U-238 > BIV of Th-232 > BIV of Cs-137. On the other hand the arrangement of BIV of different radionuclides in case of Fish animals will be follow: BIV of Cs-137 > BIV of U-232

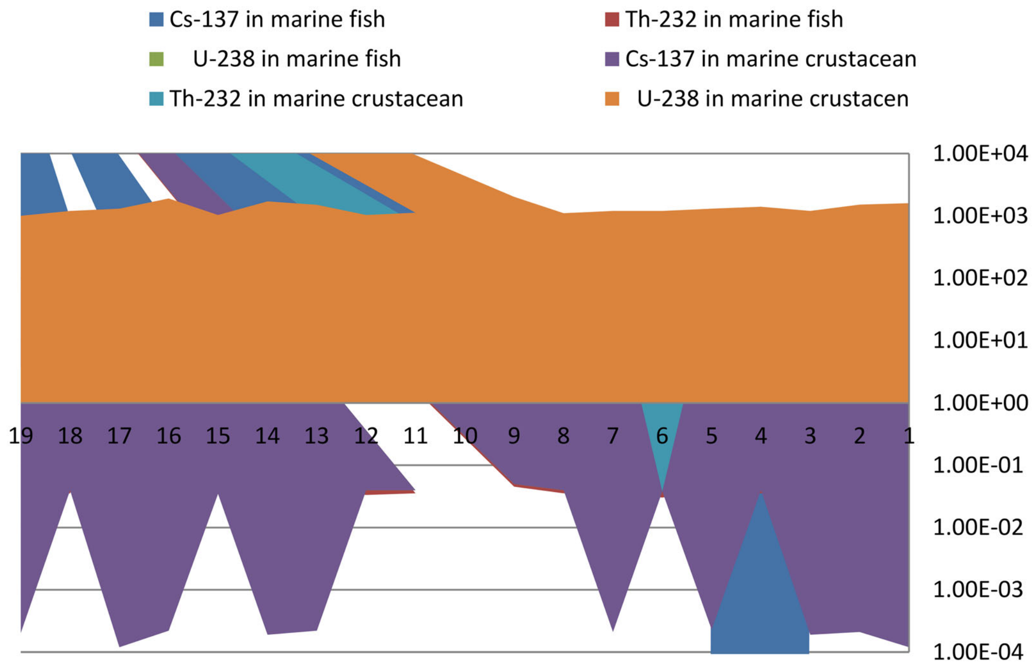

Figure 2. Distribution of bioaccumulation factor (BIV) of marine animals () as Y-axis against the selected sampling sites as X-axis by using RESRAD-Biota.

> BIV of Th-232. This arrangement can be explained as the behavior of stable elements and their corresponding radionuclides are assumed to be the similar in fish environment if they are in same physic-chemical form. K is essential macro-element and has similarity in biological tissues to Cs. Thus in cells, Cs follows K uptake mechanism.Cs-137, therefore tends to accumulate K-rich tissues, such as muscle; soft tissues account for up to 99% and bones 1-2% of the total amount of Cs-137 in fish which complied with Fesenko et al. (2011).

Dose conversion factor results

The calculated dose conversion factor in crustacean animals

In case of measuring U-238, its highest Internal Dose conversion factors (DCFs) calculated for Crustacean marine animals was (1.20E + 03) (Gy/y)/(Bq/Kg) at site (14) with, while its lowest DCFs value was (4.30E-04) (Gy/y)/(Bq/Kg) at site (7), as being showed in Table 3. While in case of natural Th-232, the highest Internal Dose conversion factors (DCFs) was 8.60E + 01 (Gy/y)/(Bq/Kg) where it is found at site (14), on the other hand its lowest Internal Dose conversion factors (DCFs) value was (2.6E-03) (Gy/y)/(Bq/Kg) at site (2). Table 3 showed that, in case of artificial Cs-137 it was found that the recorded highest Internal Dose conversion factors DCFs was 1.18E-06(Gy/y)/(Bq/Kg) site (3), while its lowest Internal Dose conversion factors (DCFs) was 1.18E-06 (Gy/y)/(Bq/Kg) site (1). The arrangement of the Internal Dose conversion factors (DCFs) for different selected radio-nuclides which were being calculated for the Crustacean will be: DCFs of U-238 DCFs > of Th-232 > DCFs of Cs-137. As the internal dose conversion factor of natural U-238 is higher in Crustacean animals than DCFs of natural Th-232 specially in sites(11,12,13,14,15,16,17,18,19, and 20) and higher than artificial cesium radionuclides as these results were complied with Fesenko et al. (2011).

The calculated dose conversion factor in fish animals

The arrangement of DCFs being calculated by RESRAD-BIOTA for different selected radionuclides in fish animals as: DCFs of Cs-137 > DCFs of Th-232 > DCFs of U-238. The statistical analysis of these results were showed that there are a positive correlation (0.866) between Internal Dose conversion factors (DCFs) of both Crustacean and Fish marine animals in case of uranium-238 with significance independent t-test value (0.000404) as, $p < .05$. This significance correlation value supporting the mechanism of transfer factor for both Fish and Crustacean animals in cas of U-238. Where its ingestion dose conversion factors depend on the chemical form of natural uranium, which entering the gastrointestinal (GI) tract that reaches body fluids of both crustacean and fish marine animals which reported by RESRAD-BIOTA, 2019. A positive correlation (0.996) between thorium Internal Dose conversion factors (DCFs) of both crustacean and fish marine animals was recorded with a significance independent t-test value (0.00017) as, $p < .05$. This significance value, it will support the mechanism of transfer factor which would being occurred for both fish and crustacean animals, as the ingestion dose conversion factor of natural thorium in case crustacean and fish animals were related to the increasing of their ingestion dose conversion factor (Zhao et al. 2001). Complying with Cs-137 results a positive correlation (0.995) between the Internal Dose conversion factors (DCFs) for artificial cesium for both crustacean and fish marine animals with a significance independent t-test value (0.00242) as, $p < .05$, this significance value support the transfer factor of Cs-137 from the crustacean to fish tissues which resemble the chemical transfer factor of stable K element on marine

Table 3. Calculations of the Internal dose conversion factors DCFs of some radio-nuclides in the (crustacean & fish) animals measured in (Gy/y)/(Bq/Kg), at the different sites using RESRAD-Biota.

Sites	Internal dose conversion factors in crustacean (Gy/y)/(Bq/Kg)			Internal dose conversion factors in fish (Gy/y)/(Bq/Kg)		
	U-238	Th-232	Cs-137	U-238	Th-232	Cs-137
1	4.33E-04	3.69E-03	1.18E-06	4.14E-04	3.70E-03	1.53E-06
2	4.73E-04	2.6E-03	1.28E-06	3.04E-04	2.60E-03	1.63E-06
3	4.38E-04	3.70E-03	1.73E-06	4.04E-04	3.10E-03	1.83E-06
4	4.36E-04	3.60E-03	*ND	4.24E-04	3.80E-03	*ND
5	4.31E-04	3.50E-03	1.53E-06	4.34E-04	3.90E-03	1.33E-06
6	4.32E-04	3.40E-03	*ND	4.14E-04	3.40E-03	*ND
7	4.30E-04	3.80E-03	1.53E-06	4.04E-04	3.60E-03	1.73E-06
8	4.38E-04	3.90E-03	*ND	4.84E-04	3.10E-03	*ND
9	4.31E-04	3.74E-03	*ND	4.64E-04	3.87E-03	*ND
10	4.39E-04	3.73E-03	*ND	4.44E-04	3.07E-03	*ND
11	1.05E + 03	8.40E + 01	*ND	4.98E-02	4.94E-02	*ND
12	1.07E + 03	8.20E + 01	2.20E-04	4.08E-02	4.74E-02	3.78E + 00
13	1.10E + 03	8.50E + 01	2.20E-04	4.88E-02	4.80E-02	3.58E + 00
14	1.20E + 03	8.60E + 01	*ND	4.11E-02	4.64E-02	*ND
15	1.07E + 03	8.30E + 01	2.20E-04	4.22E-02	4.54E-02	3.48E + 00
16	1.08E + 03	8.10E + 01	2.20E-04	4.55E-02	4.24E-02	3.28E + 00
17	1.05E + 03	8.20E + 01	*ND	4.29E-02	4.34E-02	*ND
18	1.02E + 03	8.09E + 01	2.20E-04	4.17E-02	4.44E-02	3.08E + 00
19	1.04E + 03	8.04E + 01	2.20E-04	4.67E-02	4.04E-02	3.18E + 00
20	1.02E + 03	8.08E + 01	2.20E-04	4.59E-02	4.82E-02	3.38E + 00

*ND: Non Detected.

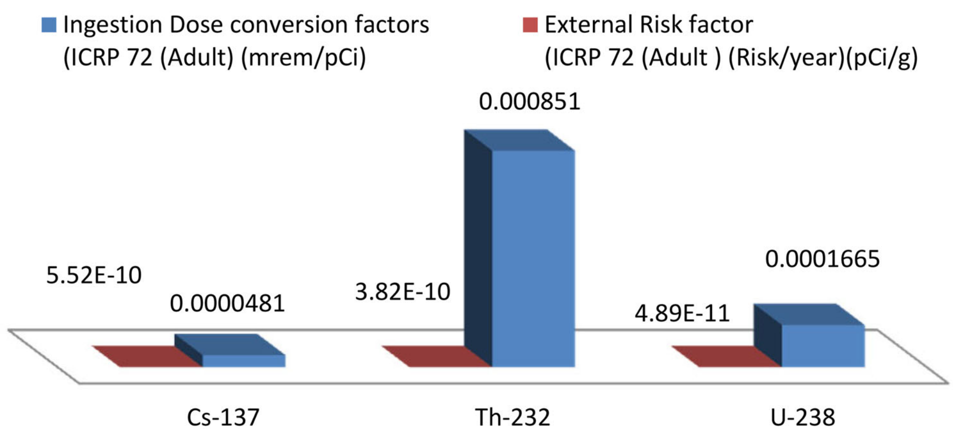

Figure 3. Relation between ingestion dose conversion factors and external human risk factor in Adult.

crustacean and fish animal. In case of fish animals the internal dose conversion factor of artificial Cs-137 is higher than DCFs of both natural thorium and uranium radionuclides as complied with Fesenko et al. (2011).

Human risk factor results

Figure 3 showed that the highest calculated ingestion conversion factors value in case of human in adult age (ICRP 72 by RESRAD Code) was found in Th-232 with 0.000853 mrem.pCi^{-1} value, while the lowest ingestion conversion factors on the same adult age (ICRP 72 RESRAD Code) was found in artificial Cs-137 with value 0.0000481 mrem.pCi^{-1}. Figure 3 showed that the highest value of external risk factor in adult age (ICRP 72) was found in artificial Cs-137 with 5.52E-10 mrem/pCi, while the lowest external risk factor on the same adult age (ICRP 72) was found in U-238 with 4.89E-11 mrem.pCi^{-1}. It was reported that in an adult biochemical reactions 10% of Cs-137 is excreted with a biological 317 half-life of 2 days, and the rest leaves the body with a biological half-life of 110 days. A maximum contaminate level (MCL) was established by EPA with 4millerms per year for beta particles and photon radioactivity from manmade radionuclides in drinking water. The average concentration of cesium-137, which is assumed to yield 4 millirems per year, is 200 picocuries per liter (pCi.L^{-1}). if other radionuclides that emit beta particles and photon radioactivity are present in addition to cesium-137, it was reported that the sum of annual dose from all radionuclides cannot exceed 4 millirems/year, (ICRP 1983). In case of age 5 (ICRP 72), Figure 4 showed that the highest calculated ingestion conversion factors value was found in Th-232 with 0.01295 mrem.pCi^{-1} while the lowest ingestion conversion factors on the same five age (ICRP 72) was found in Cs-137 with 0.00002552 mrem.pCi^{-1}. It was recorded that cesium tends to concentrate in muscles because of their relatively large mass. Like potassium, cesium is excreted from the body fairly quickly. Also the cesium clearance from the body is somewhat quicker for children, as, Cs-137 remains in the body for a relatively short time. It is eliminated more rapidly by infants and children (5, 10 and 15 age) than by adults this is complied

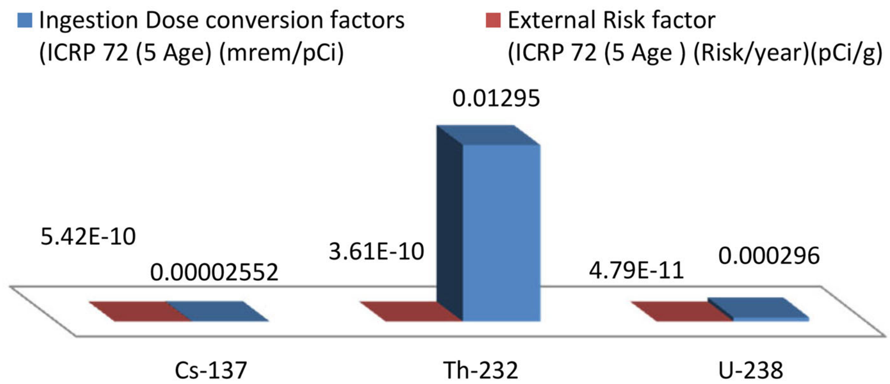

Figure 4. Relation between ingestion dose conversion factors and external human risk factor in 5 Age.

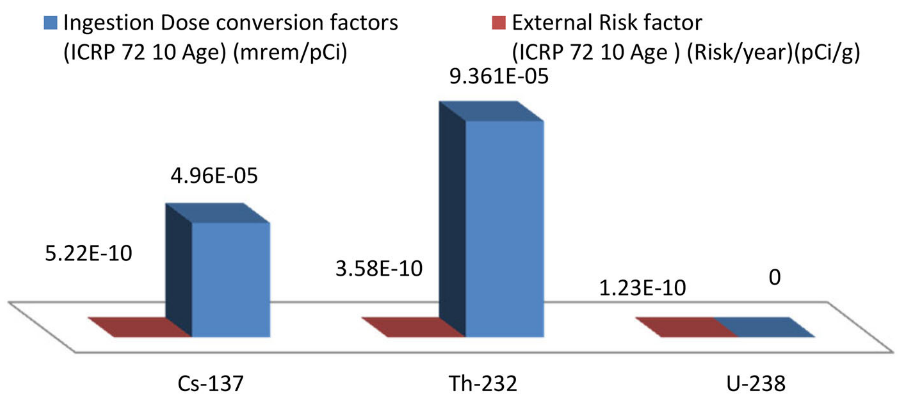

Figure 5. Relation between ingestion dose conversion factors and external human risk factor in 10 Age.

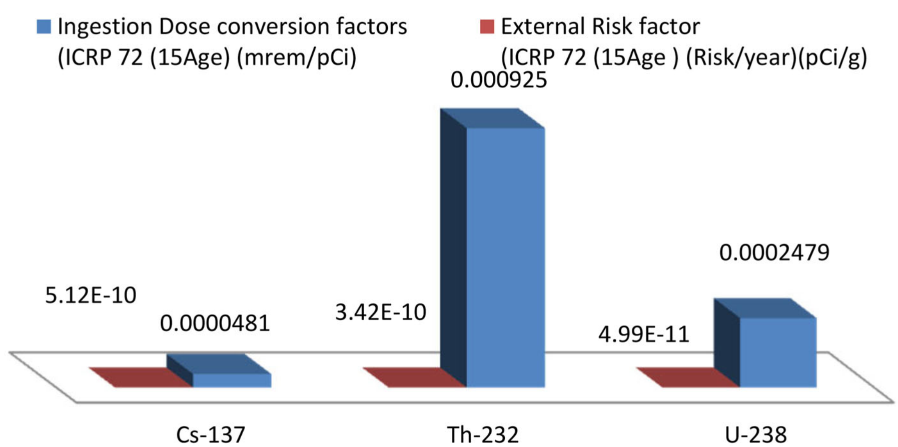

Figure 6. Relation between ingestion dose conversion factors and external human risk factor in 15 Age.

with (ICRP 1983). Figure 4 showed that the highest value of external risk factor in age 5 (ICRP 72) was found in Th-232 with 3.61E-10 mrem.pCi^{-1} while the lowest value of external risk factor in age 5 (ICRP 72) was found in U-232 with 4.79E-11 mrem.pCi^{-1}. Figure 5 showed that in case of age 10 (ICRP 72), the highest calculated ingestion conversion factors value was found inTh-232 with 0.00009361 mrem.pCi^{-1} while the lowest ingestion conversion factors on the same age 10 (ICRP 72) was found in Cs-137with 4.959E-05 mrem.pCi^{-1}. On the other hand Figure 5 showed that the highest value of external risk factor in age 10 (ICRP 72) was found in U-238 with 5.52E-10 mrem.pCi^{-1}, while the lowest value of external risk factor in age 10 (ICRP 72) was found in Cs-137 with 1.23E-10 mrem/pCi. In case of age 15, Figure 6 showed that the highest calculated ingestion conversion factors value was found inTh-232 with 0.000925 mrem.pCi^{-1}, while the lowest ingestion conversion factors on the same age 15(ICRP 72) was found in Cs-137with 0.0000481 mrem.pCi^{-1}. Figure 6 showed that the highest value of external risk factor in age 15 (ICRP 72) was found in Cs-137 with 5.12E-10 mrem.pCi^{-1}, while the lowest value of external risk factor in age 15 (ICRP 72) was found in U-238 with 4.99E-11 mrem.pCi^{-1}.

Conclusion

The study results showed that the highest concentration of radioactivity of the radionuclides was found in the range of K-40 $Bq.L^{-1}$, whereas K-40 is not a helpful parameter in RESRAD-BIOTA, as its internal dose is fixed. In contrast the highest dose conversion values for marine animals (crustacean and fish) were found in natural occurring Th-232 ($mrem.pCi^{-1}$), while the lowest dose ingestion conversion factors values were recorded in artificial Cs-137($mrem.pCi^{-1}$). On the other hand the highest value of external risk factor in case of (5, 10, 15 with adult age) was observed in artificial Cs-137, while the lowest value of external risk factor with the same ages was observed in U-238. Results showed that an increment of the calculated external risk factor values of adult than all infants (5,10and 15 ages) ages as there are a continuous replacement of new body cells during the growth stages. The arrangement of the bio-accumulation value (BIV) in Bq/kg which being calculated by using RESRAD-Biota in case of crustacean animals will be: U-238 > Th-232 > Cs-137., while the arrangement of BIV in case of fish animals will be: Cs-137 > U-232 > Th-232. On the other hand the arrangement of Internal Dose Conversion factors in case of crustacean animals will be: U-238 > Th-232 > Cs-137. While the arrangement of Internal Dose Conversion factors in case of fish animals will be: Cs-137> Th-232 > U-238. These results showed that the environmental bioaccumulation impacts of the artificial Cs-137 were very effective in both marine living organisms and the human as this support the previous studies which showed the relation of Cs-137 ingestion in the body and the probability of the human cancer risk, this will lead to continual monitoring of artificial Cs-137 in different marine coastal regions, and support the using of RESRAD BIOA software for new Environmental Impact Assessment (EIA) studies of the future coastal industrial projects.

Ethics approval

All of the experimental protocols were not need to get ethic approval as there were no experimental animals used.

Consent to publish

All of authors consent that this manuscript was published in this journal.

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