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External Radiation Dose to the Shore Crab of Chinnavilai, a High Background Natural Radiation Area

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The aim of the study was to determine the activity concentration and radiation dose of radionuclides ^{226}Ra, ^{228}Ra & ^{40}K in shore crab *Hemigrapsus Sanguineus,* in Chinnavilai, Kayakumari district, Tamil Nadu, India. Gamma spectrometry is used for determine activity concentration and radiation dose of radionuclides (^{226}Ra, ^{228}Ra & ^{40}K.). The total dose values due to both internal and external contributions by all three studied radionuclides fell between 26.51 and 53.19 µGy/day. These values are far below the dose limits (10 mGy/day) prescribed for aquatic animals by the US Department of Energy (2002) and hence the animals are safe, radiologically as far as these radionuclides are concerned. The minimum internal dose for ^{228}Ra in shore crab 0.30

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and the external dose 16.42. The total dose for ^{228}Ra in shore crab 16.72. The maximum internal dose for ^{228}Ra in shore crab 0.64 and the external dose 30.03. The total dose for ^{228}Ra in shore crab 30.67.

Keywords: Radionuclides; High Background Natural Radiation Area (HBNRA); gamma spectrometry; activity concentration; radiation dose.

1. INTRODUCTION

"Radiation is present in every environment of the Earth's surface, beneath the Earth and in the atmosphere. According to UNSCEAR [1] about 87% of the radiation dose received by mankind is due to natural radiation sources and the remaining is due to anthropogenic radiation. Natural radioactivity is mainly due to the primordial radionuclides, such as ^{40}K, and other radionuclides such as ^{238}U and ^{232}Th and their decay products, which are present at trace levels in all ground formations" [2].

"Radioecology is the study of biota with respect to radiation. The certain region has higher radiation. This region is called High Background Natural Radiation Areas, such as Australia, Brazil, China, France, India and Iron in the world" [3,4,5]. "In India there are quite a few monazite sand bearing placer deposits causing high background radiation along its long coastal line. Ullal in Karnataka, Kalpakkam in Tamil Nadu, coastal parts of Tamil Nadu and Kerala state and south western coast of India are known to be high background radiation areas" [6]. One of the areas in the south west coast where high radiation level has been reported was from coastal regions of Kanyakumai district, in Tamil Nadu.

"The radioactivity of beach sands of Manavalakurichi region along the south - west coast of India in Tamil Nadu has revealed the high potency of the monazite sands spanning across the Kadiapattinam estuary on the eastern side of Manavalakurichi" [7]. "The in situ radiometric surveys indicated that the beaches and immediate hinterlands in the west coast of southern Tamil Nadu have more radioactive when compared to the east coast" [8].

The aim of the study was to determine the activity concentration and radiation dose of radionuclides ^{226}Ra, ^{228}Ra & ^{40}K in shore crab *Hemigrapsus Sanguineus,* in Chinnavilai, Kayakumari district, tamil Nadu, India using radiation counting methods.

2. MATERIALS AND METHODS

2.1 Study Area

Chinnavilai coastal regions are mainly the study area which is a High Background Natural Radiation Area (HBNRA) in the southwest coast region of Kanyakumari district in Tamil Nadu, India (Fig. 1).

2.2 Sample Collection

The 10Kg of shore *crab Hemigrapsus sanguineus* was collected in Chinnavilai (Fig. 2). The sample was washed and dried in an oven at temperature of 100^{0}C to 120^{0}C for an hour. The samples were powdered, charred under a low flame, and then ashed at 450^{0}C to get a uniform white ash in muffle furnace. The ash sample was stored in plastic container sealed and kept for one month for the equilibrium of daughter products.

Estimation of ^{226}Ra, ^{228}Ra and ^{40}K in the shore crab samples were carried out by using high resolution Gamma ray spectrometry comprising a high purity NaI (Tl) detector (Fig. 3). Samples were counted on a Canberra make vertically oriented NaI (Tl) having a relative efficiency of 24.8% and resolution of 1.95kev for13.32kev peak of 60Co [9]. Efficiency calibration of the system is carried out by using secondary standard sources (RGU-1(400 µg/g of 238U) and RGTh-1(800 µg/g of 232Th) procured from IAEA. Estimation of natural radioactivity were carried by measuring the following Gamma energies viz., ^{226}Ra directly through the 186.2kev and indirectly by measuring the ^{214}Bi (609.3kev, 1120.2kev and 1764.5kev) and ^{214}Pb (351.9kev) photo peaks. ^{228}Ra is estimated through ^{228}Ac(911.2kev) 212Pb (238.6kev) and ^{208}Tl(2614kev) photo peaks, and estimation of ^{40}K through the 1460.8kev photo peak ^{226}Ra and ^{228}Ra were estimated by measuring different daughters that emit clear Gamma peaks of high intensity to confirm the attainment of radioactive secular equilibrium within the samples between ^{226}Ra and its daughters. All the samples were counted for 5000 seconds.

Fig. 1. Study area map chinnavilai

Fig. 2. Shore crab- *Hemigrapsus sanguineus*

Fig. 3. Gamma counting system

Calculation of the activity of radionuclides, the following formulae:

$$Activity = \frac{NetCPS \times 100 \times 1000}{E \times Q}$$

Radiation dose calculation – internal and external

The unweighted radiation dose to biota was estimated using the FASSET protocol and the dose conversion coefficient (DCC) values were taken from Ulanovsky and prohl [10].

External absorbed dose rate calculated for crabby using the following formula:

$$D^j_{ext} = \sum_i DCC^j_{ext,i} * C_{medium,i}$$

where $C_{medium,i}$ is the median concentration of the radionuclide *i* in water/soil (Bq l^{-1}, dissolved phase; Bq kg^{-1}f.w. soil); $DCC^j_{ext,i}$ is the dose conversion coefficient for external exposure [a ratio of the dose rate to the organism *j* to the average concentration of the radionuclide *i* in the environment (water) (µGy h^{-1} per Bq l^{-1}; µGy h^{-1} per Bq kg^{-1})].

The internal dose rate for biota can be derived from the activity concentration in the selected reference organism using the following equation:

$$D^j_{int} = \sum_i C^j_i * DCC^j_{int,i}$$

where C^j_i is the activity concentration of the radionuclide *i* in the biota *j* (Bq kg^{-1} f.w.) and $DCC^j_{int,i}$ is the radionuclide-specific dose conversion coefficient for internal exposure [a ratio of the dose rate to the organism to the average concentration of the radionuclide *i* in the organism *j* (µGy h^{-1} per Bq kg^{-1}f.w.)].

3. RESULTS AND DISCUSSION

3.1 Activity Concentration of ^{40}K, ^{226}Ra and 228^{228}Ra in Shore Crab

The ^{40}K activity concentrations in shore crab, the highest value of ^{40}K recorded in shore crab 127.23 ± 27.31Bq Kg^{-1} and the lowest value of ^{40}K recorded in shore crab 73.36 ± 7.33Bq Kg^{-1}. The highest value of ^{226}Ra recorded in shore crab 45.83 ± 10.5Bq Kg^{-1} and the lowest value of ^{226}Ra recorded in shore crab 15.62 ± 3.35Bq Kg^{-1}.The highest value of ^{226}Ra recorded in shore crab was 76.59 ± 16.47 Bq Kg^{-1} and the lowest value of ^{228}Ra recorded in shore crab 36.17 ± 7.77 Bq Kg^{-1} (Table 1 and Fig. 4).

Radiation dose to an organism is the total quantity of energy absorbed from ionizing radiation per unit mass of tissue (1Gy = 1J kg-1 of tissue) and the dose rate refers to the energy absorbed over time (µGy h^{-1}).

The minimum internal dose for ^{40}K in shore crab 0.53 and the external dose 0.14. The total dose for ^{40}K in shore crab 0.67. The maximum internal dose for ^{40}K in shore crab 0.92 and the external dose 0.25. The total dose for ^{40}K in shore crab 1.17. The minimum internal dose for ^{226}Ra in shore crab 5.25 and the external dose 3.87. The total dose for ^{226}Ra in shore crab 9.12. The maximum internal dose for ^{226}Ra in shore crab 15.40 and the external dose 5.95. The total dose for ^{226}Ra in shore crab 21.35.

The minimum internal dose for ^{228}Ra in shore crab 0.30 and the external dose 16.42. The total dose for ^{228}Ra in shore crab 16.72. The maximum internal dose for ^{228}Ra in shore crab 0.64 and the external dose 30.03. The total dose for ^{228}Ra in shore crab 30.67 (Table 2).

The activity of ^{40}K was found to be shore crab, range from 73.29 ± 7.33Bq kg^{-1} to 127.23 ± 27.31Bq kg^{-1}d.w. the essential element potassium performs various vital physiological functions in both plants and animals. ^{40}K enters and exists the body along with stable K and in homoeostatically regulated. [11] ^{40}K was investigated and its mean value was found to be (157 ± 17) for Sardina Pilchardus, (138 ± 14) for Mugil Cephalus, (118 ± 13) [12] reported the activity concentration for ^{40}K were 2305.8±5.61 Bq kg^{-1} and 1767.19±4.91 Bq kg^{-1} for fish samples from Borokiri (PortHarcourt) and Lagos State. These value were higher when compare to Chinnavilai coast [13].

Radium isotopes ^{226}Ra and ^{228}Ra were found to be shore crab, range from 15.62 ± 3.35 Bq kg^{-1} to 45.83 ± 10.5 Bq kg^{-1} and ^{228}Ra range from 36.17 ± 7.77 Bq kg^{-1} to 76.59 ± 16.47 Bq Kg^{-1} (f.w). Kazoka *et al*., 2023 reported ^{228}Ra (98.91 ± 3.43 Bq/kg), which ranged from (29.35–134.19) Bq/kg. The lowest combined mean of radionuclide was observed in ^{226}Ra (113.42 ± 0.10 Bq/kg), which ranged from (22.57–143.54) Bq/kg. These values were lower when compared to Chinnavilai coast.

Table 1. Activity concentration of 40K, 226Ra and 228Ra in Shore crab (*Hemigrapsus sanguineus)*

Month and year of sampling	^{40}K	^{226}Ra	^{228}Ra
April 2018	110.03 ± 23.6	33.62 ± 7.23	75.72 ± 16.27
May 2018	127.23 ± 27.31	28.13 ± 6.04	67.70 ± 14.55
June 2018	78.20 ± 16.81	19.42 ± 4.17	51.24 ± 11.01
July 2018	112.9 ± 24.27	37.36 ± 8.12	36.17 ± 7.77
August 2018	113.64 ± 24.8	19.14 ± 4.11	63.39 ± 13.63
September 2018	120.41 ± 25.89	22.39 ± 4.81	41.79 ± 8.98
October 2018	76.29 ± 16.40	32.96 ± 7.08	41.75 ± 8.97
November 2018	114.18 ± 24.55	15.62 ± 3.35	49.93 ± 10.73
December 2018	73.36 ± 7.33	20.27 ± 4.35	73.36 ± 15.77
January 2019	107.05 ± 23.02	17.29 ± 3.71	76.59 ± 16.47
February 2019	123.87 ± 26.63	45.83 ± 10.5	51.94 ± 11.16
March 2019	108.09 ± 23.24	24.50 ± 5.26	70.59 ± 15.18

Table 2. Radiation dose (µGy/day) in Shore crab (*Hemigrapsus sanguineus)*

Radionuclides		Internal	External	Total
^{40}K	Minimum	0.53	0.14	0.67
	Maximum	0.92	0.25	1.17
^{226}Ra	Minimum	5.25	3.87	9.12
	Maximum	15.40	5.95	21.35
^{228}Ra	Minimum	0.30	16.42	16.72
	Maximum	0.64	30.03	30.67

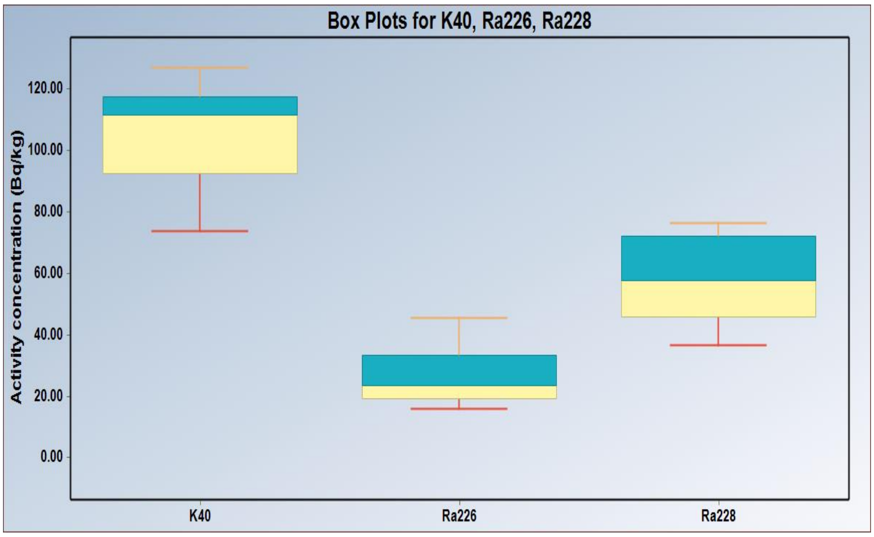

Fig. 4. Box plots for activity concentration of radionuclides in shore crab

The total dose values due to both internal and external contribution by all three studied radionuclides fell between 26.51 and 53.19 µGy/day.

4. CONCLUSION

The assessment of radiation dose delivered to marine organisms due to natural radionuclides is considered very important in view of radio ecological health. The activity concentration of radiradioactive nuclides reported from shore crab *Hemigrapsus sanguineus* found at Chinnavilai, a high background Radiation areas of Tamil Nadu in India. Many peoples are daily intake of marine food. This radiation dose limits (10 mGy/day) prescribed for aquatic animals by the US Department of Energy (2002) and hence the animals are safe, radiologically as far as these radionuclides are concerned. Chinnavilai is high radiation area but limited level of radioactivity present so it safe for human being for intake of food.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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