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Naturally Occurring Radionuclides Intake of Fish Diversity by Inhabitants around the Nuclear Power Plant, Based on the Market Basket Sampling (MBS) Approach

Kumar Pandion[1]; Suranjana V Mayani[2]; Rahul J Nikam[3]; Aditya Saran[2]; Kantha Deivi Arunachalam[2]*

[1]Center for Environmental Nuclear Research, Directorate of Research, SRM Institute of Science and Technology, SRM Nagar, Kattankulathur, 603203, Chennai, TN, India.

[2]Faculty of Sciences, Marwadi University, Rajkot, Gujarat, India, 360 003.

[3]Faculty of Law, Marwadi University, Rajkot, Gujarat, India, 360 003.

***Corresponding Author(s): Kantha Deivi Arunachalam**

Faculty of Sciences, Marwadi University, Rajkot, Gujarat, India, 360 003.

Emaail: kanthadevi.arunachalam@marwadieducation.edu.in

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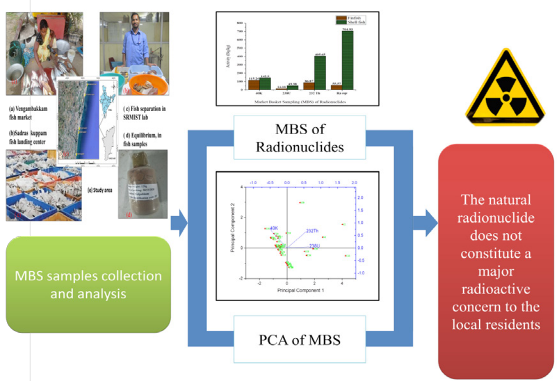
Keywords: Fish diversity; Market Basket Sampling (MBS); Radionuclides; Dose assessment; Coastal zone.

Abstract

As a part of our baseline study, the distribution of ^{238}U, ^{232}Th, and ^{40}K was analyzed by Market Basket Sampling (MBS) methods in different age group people in and around the coastal zone. The average concentrations of natural radionuclides like ^{238}U, ^{232}Th, and ^{40}K (n=40) in finfish diversity (14.08, 86.87, 115.26) Bq kg^{-1} and shellfish diversity (49.98, 405.65, 142.90) Bq kg^{-1}. It was detected that the concentration of radionuclides in shellfish was higher compared to finfish. The annual intake, ingestion dose, lifetime carcinogenic risk, and cancer risk due to ^{238}U, ^{232}Th, and ^{40}K was calculated by market basket sampling methods in different age groups of 1- 4, 5-9, 10-14, 15-17 years, adult, pregnant women, and fisherman. Our results in the coastal zone study were compared with Hospital-Based Cancer Registry. The radionuclide activities, analyzed statistically using Pearson correlation, principle component, and cluster analysis showed that there is no major radioactive concern to the local residents.

Graphical Abstract



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Introduction

The higher radioactivity of naturally occurring radioactive material (NORM) in fish diversity [1] is due to the accumulation of the marine environment in to the fish diversity through different ways such as ingestion and deposition. The external factors play a major role on the human body [1] for example due to pH the ingestion of radionuclides from the fish diversity NORM levels was high. The radioactivity in marine organisms is many times higher than coastal water because the marine organisms absorb high levels of radionuclides from the seawater, [2,3].

[4] found that the main of the ingested dose usual by the general inhabitants is due to the NORM. The natural radiation in fish diversity receives significantly less consideration than man-made radionuclides. This may be due to their natural origins and the lack of legislation governing their concentration in fishes and the analysis of natural radionuclides is both expensive and time-consuming.

Radionuclides in the marine environment can be transferred by attaching to plankton, and contaminate marine organisms such as fish and shellfish which varies due to the solubility variation in the sea water for example U,^{222}Rn and ^{232}Rn are soluble in coastal water while Thorium is completely unsolvable [5]. More research on benthic organisms and shellfish helps us to understand the accessibility and transfer of radionuclides between deposits of mud, coastal waters, and bottom species. In fact the bottom species such as the mussel, winkle, and prawn are popular seafood that are regularly consumed by humans cause increasing human radiation exposure due to the bioaccumulation of radionuclides, [6].

Komperd and Renaud [7,8] have found that fish diversity is the single diet group that contributes to the higher ingestion dose in several countries due to the relatively high content of NORM in fish diversity. The natural radioactivity concentrations have also been demonstrated to differ considerably amongst species [5,9,10]. As a result, it is critical to consider activity data for each species that are actually consumed in the specific country or region when making relevant dose estimations for fish and shellfish.

The present study is to determine the radioactive dose in fish diversity consumed for ^{238}U, ^{232}Th, and ^{40} K through Market Basket Sampling (MBS) for the internal dosage. The radioactivity of ^{238}U, ^{232}Th, and ^{40} K was determined using an HPGe. The yearly consumption and the effective dose, lifetime carcinogenic risk a, computation of cancer risk from market basket sampling methods, and HBCR were also evaluated using ^{238}U, ^{232}Th, and ^{40} K in the fish diversity.

Material and methods

Study area

The five coastal stations (Sadras, Meyyar, Wyalli, Mahabalipuram, and Kokkilamedu) were selected for their estimations of ^{238}U, ^{232}Th, and ^{40}K intake from market basket sampling dietary sources. Mahabalipuram Beach is a popular tourist attraction known for its seashore temples. It is 8 km north of MAP. At the end of DAE campus, 5 kilometers north of MAPS, Kokkilamedu station is located. Meyyar is a station fishermen community involved fishing activities at Meyyar. 5 kilometers south of MAPS Sadras is located. In DAE Township, 8 kilometers south of MAPS is Wyalli. Figure 1 shows the market basket sampling methods data obtained along the Kalpakkam coastline zone.

Collection of market basket sampling approach for fish diversity samples

Market basket sampling approach for fish samples are collected in the five coastal zones, and brought to the SRMIST for processing. Market basket sampling methodology samples were kept in ice box upon arrival at SRMIST, and species identification was done at the ZS) in Chennai. Every time 5 kg of fish species were caught by the fisherman throughout the season, they were bought. The fish were cleaned, and edible parts were removed, weighed, and stored in an icebox for radioactive analysis. S. Figure 1 shows the sample questionnaire in English for subject market basket sampling methods used in around Kalpakkam coastal zone.

Radioactivity analysis

The dehydrated finfish and shellfish were crushed into fine particles and through sieved a 201 mm for radioactivity analysis. The samples were used to put equilibrium. Then, using the HPGe, samples were exposed to gamma spectral research to compute activity.

Health risk based on the fish diversity

Assessment of ingestion dose

The radioactivity in Bq kg^{-1} per day ingesting was taken based on the MBS sample consumption data provided by National Nutritional Monitoring Board (NNMB) based on that to calculate the consumption dose.

D = Df * U * Cd

Consumption dose (D) (Sv y^{-1}). Df - coefficient factor. U - Yearly intake of the food (kg y^{-1}). As to age, the finfish and shellfish were collected from the NNMB. Cd - the normal concentration. The radioactivity was assessed using dose conversation factors [11].

Carcinogenic risk assessment

By multiplying the ADD by the SF and the length of lifetime, the excess lifetime carcinogenic risk may be calculated (75.2 years). The SF is compared with the table [12]. The radionuclides risk exposure to different body parts. Based on that USEPA reference the radioactivity were calculated [13]. The risk has been connected to doses [14]. The following formula used.

Risk =ADD*Sfo* exposure duration

Cancer Risk in MBS for fish diversity

The cancer risk of NORM was calculated based on the Guidelines of Environment Protection Action [15] for ^{238}U, ^{232}Th, and ^{40}K. The risk assessment for the ingestion pathway was calculated using the equation.

$$\boldsymbol{Cancer\ Risk = Sf \times I}$$

The forecast intake of any radioactivity using the equation

$$\boldsymbol{I = CF \times IR \times FI \times EF \times ED}$$

In the absence of more evidence; a conservative method can assume that the fraction expended from a contaminated basis is 100% or 1%. [16].

Hospital Based Cancer Registry

The study was examined based on the Cancer Institute data this database gathers patient records by the cancer epidemiological registration methods [17-19] and generates a database on cancer cases in an exact hospital.

CCIR= [New tumor cases in a given year/estimated inhabitants in that same year] × 100000.

Statistical analysis

The origin 2018 program was using the Pearson correlation, principal component, and cluster analysis.

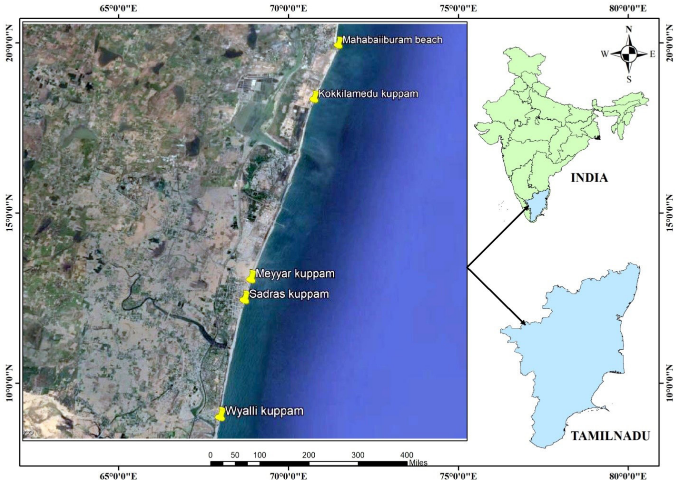

Figure 1: Shows the study area map.

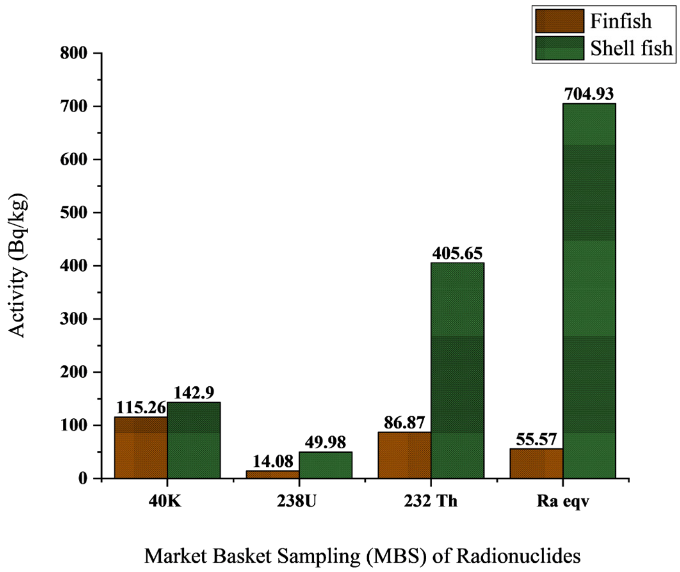

Figure 2: Shows the radionuclides in market basket sampling.

Result and discussion

Assessment of market basket sampling methods in finfish

The activity of NORM measured in market basket sampling methods. The NORM activity of finfish around the five coastal zones is presented in Table 1. The ^{40}K in the finfish ranged from 11.23 to 239.53 (Bq kg^{-1}) with the mean 119.24 (Bq kg^{-1}). Higher range of ^{40} K 239.53 (Bq kg^{-1}) was observed in seven finger threadfin and the lower activities of 11.23 (Bq kg^{-1}) were observed in freckled goatfish. The reason for the highest ^{40}K may be the transfer factor of ^{40}K is higher than some natural radioisotopes. The reported results by [20] reported the concentra-

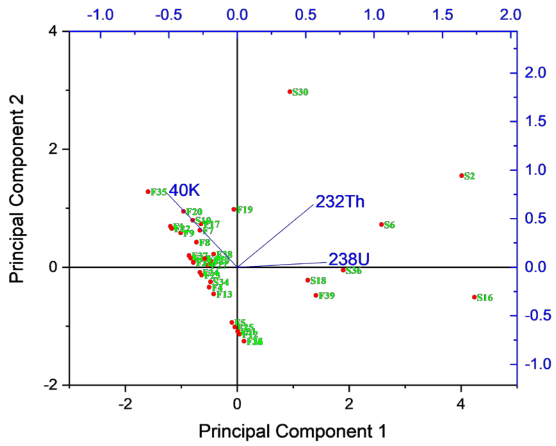

Figure 3: Shows Principle component analysis of Market Basket Sampling (MBS) and radionuclides distribution around coastal zone. (F1) Coach whips trevally, (F3) Brown stripe red snapper, (F4) Japanese threadfin bream, (F5) Common pony fish (F7) Striped eel catfish, (F8) Snakefish, (F9) Saddle grunt, (F11). White cheek monocle bream, (F12) Freckled goatfish, (F13) Spindle croaker, (F14) Fringe fin zebra sole, (F15) Malabar thryssa, (F17). Indian sweeper, (F19) Scaly whip ray, (F20) Pug nose pony fish, (F21). White-spotted spine foot, (F22) Flat needlefish, (F23) Jarbua terapon, (F24) Flathead grey mullet, (F25) Indian oil sardine, (F26) Indian mackerel, (F27) Savalai hairtail, (F28) Devis' anchovy, (F29)Three spotted flounders, (F31) Mustached thryssa, (F32) African sea catfish, (F33) Silver sillago, (F35) Seven finger threadfin, (F37) Longhead grunt, (F38) Wavy-lined grouper, (F40) Commerson's sole, (S2) Giant tiger prawn, (S6)Flathead lobster, (S10)swimming crab , (S16) Indian white prawn, (S18) Crucifix crab, (S30) three spot swimming crab, (S34)big fin reef squid, (S36) ridged swimming crab, (F39)Banana prawn.

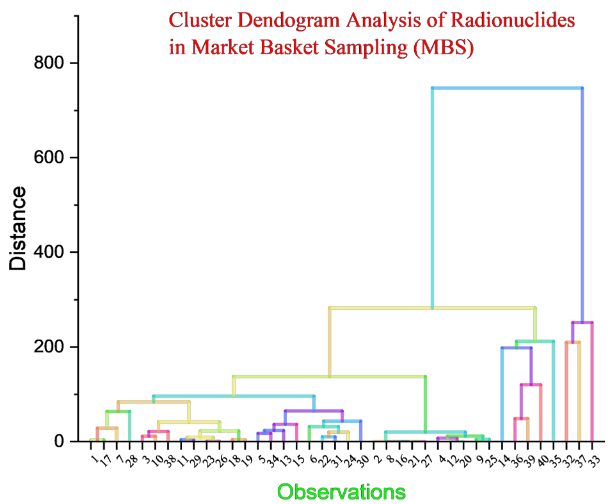

Figure 4: Showing cluster dendogram analysis of Market Basket Sampling (MBS) and radionuclides distribution around coastal zone (1) Coach whips trevally, (3) Brown stripe red snapper, (4) Japanese threadfin bream, (5) Common pony fish, (7) Striped eel catfish, (8) Snakefish, (9) Saddle grunt, (11) White cheek monocle bream, (12) Freckled goatfish, (13) Spindle croaker, (14) Fringe fin zebra sole, (15) Malabar thryssa, (17) Indian sweeper, (19) Scaly whip ray, (20) Pug nose pony fish, (21) White-spotted spine foot, (22) Flat needlefish, (23) Jarbua terapon, (24) Flathead grey mullet, (25) Indian oil sardine, (26) Indian mackerel, (27) Savalai hairtail, (28) Devis' anchovy, (29) Three spotted flounders, (31) Mustached thryssa, (32) African sea catfish, (33) Silver sillago, (35) Seven finger threadfin, (37) Longhead grunt, (38) Wavy-lined grouper, (40) Commerson's sole, (2) Giant tiger prawn, (6) Flathead lobster, (10) swimming crab, (16) Indian white prawn, (18) Crucifix crab, (30) three spot swimming crab, (34) big fin reef squid, (36) ridged swimming crab, (39) Banana prawn.

Table 1: Show the activity of NORM measured in market basket sampling (MBS) approach in finfish around the Kalpakkam coastal. Zone.

S. No	Sample-ID	Location	Common name	^{40}K (Bq kg^{-1})	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})
1	F1	Kokkilamedu	Coach whip trevally	183.92±73.78	BDL	BDL
2	F3	Mahabalipuram	Brown stripe red snapper	BDL	BDL	BDL
3	F4	Meyyar	Japanese threadfin bream	86.73±65.46	BDL	BDL
4	F5	Sadras kuppam	Common pony fish	29.89±7.86	BDL	BDL
5	F7	Sadras kuppam	Striped eel catfish	147.94±66.77	BDL	107.74±14.64
6	F8	Kokkilamedu	Snakefish	141.35±75.29	BDL	63.16±15.90
7	F9	Sadras kuppam	Saddle grunt	166.92±57.95	BDL	24.11±11.61
8	F11	Sadras kuppam	White cheek monocle	BDL	BDL	BDL
9	F12	Wyalli kuppam	Freckled goatfish	11.23±67.41	BDL	BDL
10	F13	Sadras kuppam	Spindle croaker	75.72±63.58	BDL	BDL
11	F14	Mahabalipuram	Fringe fin zebra sole	133.14±71.08	BDL	BDL
12	F15	Sadras kuppam	Malabar thryssa	22.92± 8	BDL	BDL
13	F17	Sadras kuppam	Indian sweeper	152.77±69.2	BDL	127.69± 15.48
14	F19	Meyyar	Scaly whipray	150.54±76.23	14.08±11.14	209.93±17.77
15	F20	Sadras kuppam	Pugnose pony fish	183.05±72.64	BDL	90.65±15.45
16	F21	Kokkilamedu	White-spotted spine foot	BDL	BDL	BDL
17	F22	Sadras kuppam	Flat needlefish	180.67±66.41	BDL	BDL
18	F23	Meyyar	Jarbua terapon	106.09±68.95	BDL	BDL
19	F24	Wyalli kuppam	Flathead grey mullet	110.26±62.06	BDL	BDL
20	F25	Sadras kuppam	Indian oil sardine	22.93± 8.03	BDL	BDL
21	F26	Mahabalipuram	Indian mackerel	BDL	BDL	BDL
22	F27	Sadras kuppam	Savalai hair tail	107.63±65.37	BDL	51.33±13.49
23	F28	Meyyar	Devis' anchovy	126.65±70.29	BDL	BDL
24	F29	Sadras kuppam	Three spotted flounders	108.93±60.94	BDL	71.62±12.93
25	F31	Sadras kuppam	Moustached thryssa	15.71±7.68	BDL	BDL
26	F32	Sadras kuppam	African sea catfish	126.19±72.94	BDL	BDL
27	F33	Mahabalipuram	Silver sillago	BDL	BDL	BDL
28	F35	Meyyar	Seven finger threadfin	239.53±75.51	BDL	BDL
29	F37	Kokkilamedu	Longhead grunt	137.28±63.32	BDL	BDL
30	F38	Sadras kuppam	Wavy-lined grouper	111.58±	BDL	100.81±1644
31	F40	Meyyar	Commerson's sole	117.33±67.80	BDL	54.17±14.19
Mean				115.26	14.08	86.879
Standard Deviation				55.722	7.912	71.809
Range				11.23to 239.53	14.08	24.11 to 209.93

Table 2: Show the activity of NORM measured in market basket sampling (MBS) approach of shellfish around the Kalpakkam coastal zone.

S,No	Sample-ID	Location	Common name	^{40}K (Bq kg^{-1})	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})
1	F2	Wyalli kuppam	Giant tiger prawn	BDL	60.43±17.77	916.49±31.33
2	F6	Meyyar kuppam	Flathead lobster	BDL	30.85±15.84	654.46±27.71
3	F10	Meyyar kuppam	Swimming crab	164.89±72.21	BDL	104.27±15.82
4	F16	Meyyar kuppam	Indian white prawn	BDL	142.94±21.84	156.13±38.68
5	F18	Sadras kuppam	Crucifix crab	BDL	10.23±12.91	346.11±21.74
6	F30	Wyalli kuppam	Three spot swimming crab	173.98±69.04	BDL	816.16±14.69
7	F34	Sadras kuppam	Big fin reef squid	89.84±57.93	BDL	18.91±11.69
8	F36	Sadras kuppam	Ridged swimming crab	BDL	30.21± 13.76	390.01±22.75
9	F39	Sadras kuppam	Banana prawn	BDL	25.27±12.10	248.31±19.19
Mean				142.903	49.988	405.65
Standard Deviation				46.178	48.369	320.660
Range				89.84 to 173.98	10.23 to142.94	18.91 to 916.49

Table 3: Shows annual effective dose due to ingestion of MBS.

S.No	fishes	Age Group	^{40}K (Bq kg^{-1})	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})
1	Finfish	1 years	3.66E-06	1.18E-05	3.34E-05
		5 years	3.66E-06	1.67E-05	5.19E-05
		10 years	3.95E-06	2.86E-05	7.51E-05
		15 years	3.63E-06	5.05E-05	0.000102
		Adult	3.24E-06	2.84E-05	0.000102
		Pregnant women	3.50E-06	3.08E-05	0.000111
2	Shellfish	1 years	4.38E-06	2.99E-05	0.000133
		5 years	4.38E-06	4.23E-05	0.000207
		10 years	4.74E-06	7.27E-05	0.0003
		15 years	4.36E-06	0.000128	0.000407
		Adult	3.88E-06	7.23E-05	0.000409
		Pregnant women	4.20E-06	7.82E-05	0.000442

Table 4: Shows cancer risk due to ingestion of MBS.

S. No	Fishes	Age group	^{40}K (Bq kg^{-1})	^{238}U (Bq kg^{-1})	^{232}Th (Bq kg^{-1})
1	Finfish	1 years	0.000161	6.72E-05	0.000533
		5 years	0.000363	0.000151	0.001199
		10 years	0.000565	0.000235	0.001865
		15 years	0.000686	0.000286	0.002265
		Adult	0.002824	0.001177	0.009327
		Pregnant women	0.002824	0.001177	0.009327
2	Shellfish	1 years	0.000193	0.000171	0.002129
		5 years	0.000435	0.000384	0.00479
		10 years	0.000677	0.000598	0.007451
		15 years	0.000822	0.000726	0.009048
		Adult	0.003385	0.002989	0.037256
		Pregnant women	0.003385	0.002989	0.037256

Table 5: Shows total life time cancer risk due to ingestion of MBS.

S. No	Fishes	Age group	Total lifetime cancer risk through ingestion
1	Finfish	1 years	0.000254
		5 years	0.000571
		10 years	0.000889
		15 years	0.001079
		Adult	0.004443
		Pregnant women	0.004443
2	Shellfish	1 years	0.000831
		5 years	0.00187
		10 years	0.002909
		15 years	0.003532
		Adult	0.014543
		Pregnant women	0.014543

Table 6: Shows computation of cancer risk assessment from MBS.

S.No	Fishes	Morbidity risk from natural radionuclides via MBS						
		Radionuclides	1 years	5 years	10 years	15 years	Adult	Pregnant women
1	Finfish	^{40}K (Bq kg^{-1})	0.000112	0.000252	0.000392	0.000476	0.001962	0.001962
		^{238}U (Bq kg^{-1})	4.70E-05	0.000106	0.000164	0.0002	0.000822	0.000822
		^{232}Th (Bq kg^{-1})	0.000373	0.000839	0.001305	0.001584	0.006523	0.006523
2	Shellfish	^{40}K (Bq kg^{-1})	0.000134	0.000302	0.00047	0.000571	0.002351	0.002351
		^{238}U (Bq kg^{-1})	0.000119	0.000269	0.000418	0.000507	0.002088	0.002088
		^{232}Th (Bq kg^{-1})	0.001489	0.00335	0.005211	0.006328	0.026057	0.026057

Table 7: Shows radionuclides correlations among the variables.

	^{40}K	^{238}U	^{232}Th
^{40}K	1	-0.352	-0.163
^{238}U	-0.352	1	0.403
^{232}Th	-0.163	0.403	1

Table 8: Shows the natural radionuclides concentration reported for dietary studies around the world.

Places	^{40}K	^{238}U	^{232}Th	References
Rio de Janeiro, Brazil		9	26	Dejanira da Costa Lauria,2012 (134)
Japan	85	7		Sugiyama et al., 2007 (124)
India	33.47 ± 0.79	-	-	Basu.2015 (135)
Korea	51	-	-	Chung et al., 2000 (136)
Kalpakkam	156.08	34.55	356.51	Present Study

tion of 88 Bq kg^{-1}, which were within the range of the present study. However, potassium is a vital biotic element; the activity in animal tissue is tightly regulated by metabolism.

The ^{238}U in the finfish ranged from 14.08 (Bq kg^{-1}) with the mean 14.08 (Bq kg^{-1}) fresh weight was observed in Scaly whip ray and among the analyzed 31 samples, 21 samples were in BDL. Have [21] reported that the fish category shows the concentration of 10 Bq kg^{-1} fresh weights of ^{238}U & ^{234}U in New York. From [22] the Portuguese coast ranged from 2000-24000 mBq kg^{-1}. Compare to other reports, the present study is lower. However, our values of the ^{238}U activity ratio are similar in fish, which shows that Uranium isotopes ^{238}U are radioactive equilibrium. The activity of NORM measured in market basket sampling of finfish around the Kalpakkam coastal zone is presented in Figure 2.

The ^{232}Th in the finfish ranged from 24.11 to 209.93 (Bq kg^{-1}) with the mean 86.87 (Bq kg^{-1}). Higher activities of ^{232}Th 209.93 (Bq kg^{-1}) were observed in Scaly whip ray and the lower activity of 24.11 (Bq kg^{-1}) was observed in saddle grunt and among the analyzed 31 samples, 30 samples were in BDL. The ^{232}Th concentrations were higher than the 1 mBq kg^{-1} reported by [21]. The [22] from the Portugal coast has reported the mean activity of ^{232}Th ranged from 0.3-3 mBq kg^{-1}. In Korea, [23] reported the activity of 1100 mBq kg^{-1}. Furthermore, when compared to other research from around the world, our reported ^{232}Th is lower.

Activity of market basket sampling in shellfish

The activity of NORM measured in market basket sampling methods of shellfish around the Kalpakkam coastal zone is presented in table 2. The ^{40}K in the shellfish ranged from 89.84 to 173.98 (Bq kg^{-1}) with the mean 49.98 (Bq kg^{-1}). Higher activity of ^{40}K 173.98 (Bq kg^{-1}) was observed in three spot swimming crab and the lower activity of 89.84 (Bq kg^{-1}) were observed in big fin reef squid. Lambrechts et al., 1992 [24] discussed about ^{40}K represents more than 80% of aquatic components. In the present study crustaceans' radioactivity of ^{40}K level is BDL. Pinero-Garca et al 2022 [25] also mentioned that crustaceans have lower potassium levels. Furthermore, the lower salinity (15-18 ps) of the Kattegat Sea, where these crustaceans were collected, may have contributed to the low amounts of ^{40}K seen in blue mussels and shrimps.

The ^{238}U in MBS of the shellfish ranged from 10.23 to 142.94 (Bq kg^{-1}) with the mean 14.08 (Bq kg^{-1}) higher activity of ^{238}U 142.94 (Bq kg^{-1}) were observed in Indian white prawn and the lower activity of 10.23 (Bq kg^{-1}) were observed in crucifix crab. Also highlighted [26] the greatest uranium isotope activity concentrations found in shellfish samples, with one sample having 0.417 (Bq kg^{-1}) uranium. The uranium isotope levels found in crustaceans are comparable with international statistics on seafood. Figure 2 shows the concentrations of naturally occurring radionuclides observed in the MBS of shellfish in the Kalpakkam coastal zone.

The ^{232}Th in MBS of the crustaceans ranged from 18.91 to 916.49 (Bq kg^{-1}) with the mean 405.65 (Bq kg^{-1}). Higher activity of ^{232}Th 916.49 (Bq kg^{-1}) was observed in giant tiger prawns and the lower activity of 18.91 (Bq kg^{-1}) was observed in big fin reef squid. Also looked [27] at the annual intake of ^{232}Th from the fish diet, which ranged from 0.09 to 0.42 Bq per year. Our estimate of the concentration in shellfish samples is much higher than that previously reported.

In general, shellfish have more activity than finfish in our current study. Changes in NORM concentration across different types of fish diversity, according to [28], could be due to differences in absorption, eating habits, and other variables in the marine environment, such as radionuclide chemical form, salinity, temperature, and pH. Also discussed [29] about shellfish were present in the Bay of Bengal, which is safe for the local resident. Table 8 shows the natural radionuclides concentration reported for dietary studies around the world. Our results could not be compared due to a lack of data on MBS of the NORM concentration in finfish and shellfish dietary components around the Kalpakkam coastal zone. As a result, estimating NORM concentration in the MBS component from the Kalpakkam coastal zone of India is safe for consumption.

Dose assessment

Natural radionuclides are created by radioactive materials in the earth's crust as well as natural radioactivity from deep space. As a result, they are always present in the environment and can be found in various concentrations in food. Intakes of radionuclides by swallowing can expose people to radiation [30-34].

Food consumption rate of fish diversity

The NNMB reports were used to classify the age groups around Kalpakkam coastal zone and the food consumption rates for fish intake [18]. The annual intake for the different age groups was calculated for kg/y as shown in S Table 1.

Yearly effective dose due to ingestion of MBS

From Table 3 the annual actual dose due to intake of MBS via potassium, uranium, and thorium in different fishes was observed (finfish and shellfish). In case of finfish it can be determined that pregnant women are confirmed to be at risk due to the absorption of MBS but that also less than one safe for consumption around the five coastal zone. The yearly effective dose via potassium, uranium, and thorium for age group 1-4 years (3.66E-06 to 3.34E-05), age group 5-9 years (3.66E-06 to 5.19E-05), age group 10-14 years (3.95E-06 to 7.51E-05), age group 15-17 years (3.63E-06 to 1.02E-04), adult (3.24E-06 to 1.02E-04), pregnant women (3.50E-06 to 1.11E-04), and fisherman community (3.24E-06 to 1.02E-04). The yearly effective absorption dose of ^{40}K, ^{238}U and ^{232}Th is (3.83E-06 to 4.67E-06 mSv/y, 1.30E-05 to5.58E-05 mSv/y and 1.23E-04 to 4.08E-04 mSv/y).

In the case of shellfish it can be decided that pregnant women are more confirmed to be at risk due to the ingestion of MBS but that also less than one so safe for consumption around the five coastal zone. The yearly effective dose via potassium, uranium, and thorium for age group 1-4 years ranged from 4.38E-06 to 1.33E-04, age group 5-9 years (4.38E-06 to 2.07E-04), age group 10-14 years (4.74E-06 to 3.00E-04), age group 15-17 years 44.36E-06 to 4.07E-04, adult (3.88E-06 to 4.07E-04), pregnant women (4.20E-06 to 4.42E-04), and fisherman community (3.88E-06 to 4.09E-04). The yearly effective absorption dose of ^{40}K, ^{238}U and ^{232}Th is (3.88E-06 to 4.74E-06 mSv/y, 2.99E-05 to 1.28E-04 mSv/y and 0.000133 to 0.000442 mSv/y).

Potassium in fish and shellfish" contributes significantly to exposure in the general human, according to [35]. The ^{238}U, ^{222}Rn, and ^{232}Rn are all soluble in seawater, according to [36]; however, substances can dissolve in coastal water to sediment, and floating marine organisms contaminate marine creatures such as fish, crabs, and a variety of shellfish.

Cancer risk due to absorption of MBS

When finfish and shellfish gather the desired radionuclides from the surrounding waters, they can be used as bio-indicators [37]. Monitoring radioactivity in finfish and shellfish is critical, according to [38], because the contribute significantly to the natural radionuclides dose received by humans who consume them. Table 4 shows the cancer risk associated with MBS ingestion in various fish (finfish and shellfish) that do not offer a considerable radiological concern to public health and are considered safe for human consumption in the Kalpakkam coastal zone.

Table 5 shows the total lifetime cancer risk from MBS consumption. Shellfish showed more activity than finfish. We can deduce from this that, except for pregnant women, the other age groups had no main radioactivity impact on community. Many researchers have also predictable the total lifetime cancer risk associated with radioactive ingesting by MBS. Discussed with [39] more activity was found in "fish and shellfish" was 0.145 (Bq kg^{-1}).

Also [40] discussed the radioactivity concentrations of finfish and shellfish, finding that mean activity of ^{232}Th and ^{40}K ranged 7 1 to 190 10 and 210 50 to 360 40 Bq kg^{-1}, correspondingly, in fish samples. Similarly, the activity of ^{232}Th and ^{40}K in crustacean samples ranged from 5.0 2 to 53 10 and 130 40 to 240 70 Bq kg^{-1}, respectively. Furthermore, in all samples, the activity of ^{40}K more concentration compares to be other radionuclides. When comparing the current study to previous studies in the same location for finfish and shellfish [41,42], Different radioactive elements have grown significantly in those marine species in the Bay of Bengal.

This rise can be attributed to the Bay of Bengal diverse range of activities all of which have diversified over time. The multifunction and management change in the marine environment. Overall, it can be determined that ingesting MBS in the Kalpakkam coastal zone has no major radioactivity to public health, and MBS are regarded safe for human ingesting.

Computation of Cancer Risk from MBS

Computations of cancer risk assessment were analyzed MBS samples from different fishes (finfish and shellfish) assed. Table 6 specified that the NORM limit was high for ^{232}Th, and the low risk was detected for ^{40}K and ^{238}U in all villages. The adult, pregnant women and fisherman age people will be at high risk related to other age groups.

The hazard observed for MBS samples from finfish order 0.000177333, 0.000399, 0.000620333, 0.000753333, 0.003102333, 0.003102333 and 0.003102333 for 1-4, 5-9, 10-14, 15-17 years, adult, pregnant women and fisherman age groups. Shellfish order 0.000580667, 0.001307, 0.002033, 0.002468667, 0.010165333, 0.010165333 and 0.010165333 for 1-4, 5-9, 10-14, 15-17 years adult, pregnant women and fisherman age groups. Compare to MBS samples from finfish to shellfish is more activity of cancer risk. The USEPA deliberates extra cancer risks that are less than 1E-06, or one in ten thousand, to be inconsequential, and if the risk is greater than 1E-04, it is large enough to warrant remediation [43].

Prevalence of Tumor

In 2016, the population of Kalpakkam was 94,968 people, with 44,028 men and 50,940 women, according to Indian census data. For the five years from 2012 to 2016, 4900 cancer occurrence cases were recognized at the Cancer Institute in Chennai. In this area, the overall crude cancer occurrence rate was 112.9 percent. The cancer institute in Chennai was where the majority of people was first diagnosed or registered for TNCR, followed by Government Cancer Hospitals [44]. Reviewed the [45] epidemiology of India's most frequent malignancies. Discussed [46] about overview of cancer registration in India. Tobacco-related cancers (oral cavity, oropharynx, hypopharynx, esophagus, stomach, larynx, lung, pancreas, and urinary bladder) affect 47 % of men and 18% of women [45]. Although the prevalence of cancer cases observed around the Kalpakkam is low when compared to cancer incidences reported by various authors on man-made and natural radionuclides.

Statistical studies

Pearson correlation analysis

Market basket sampling and radioactive distribution have a link that can discover contamination sources in radionuclide routes. The correlation coefficient between market basket sampling and radionuclides is strong, showing their same nature, reciprocal dependency, and identical behavior during the study. Correlation was used as calculating the linear Pearson correlation coefficient.

To establish correlations among the variables, the Pearson matrices for market basket sampling and radioactivity in five coastal zones are shown in table 7. The ^{40}K and other radionuclides have a strong positive relationship. ^{238}U radionuclides had a negative connection with ^{40}K radionuclides, whereas ^{232}Th radionuclides had a positive correlation with ^{238}U but a negative correlation with ^{40}K.

PCA

The first PCA attempts to capture as much difference in the information as possible. The entire variance and section matrices market basket sampling and radioactivity PCA results are shown in S Table 2. Conferring to these findings, the market basket sampling and radionuclide distributions could be clustered into 3 component models that explained 100% of the data variation. These conclusions were supported by the results of the Eigenvalue correlation research. PC1 explained 54.11 percent of the total variance, with an eigenvalue of 1.62. This component could be labeled as "^{40}K."

With an eigenvalue of 0.83, the 2 component explained 27.93 % of the total variance, while the third component (PC3), with an eigenvalue of 0.53, explained 17.96 %. This component could be identified using the terms "^{238}U and ^{232}Th." clustering was achievable in the impacts of all variables inside the 3 dimensional planes, as shown in Figure 3. The data suggested that the number of market basket sampling was linked to radionuclides.

Cluster analysis

The clustering approach considers item dissimilarities or distances while generating clusters. Each year's radioactive distribution and market basket sampling were combined. The abundance data were clustered using the entire linkage method, which was based on Bray-Curtis similarities (log 1transformed). The findings of cluster analysis for market basket sampling matrices and radionuclide delivery are shown in Figure 4. Based on the cluster results, it was able to found meaningful groupings with the maximum degree of similarity. Cluster analysis produced 27 distinct clusters based on the correlation distance of the elements under examination.

Cluster group 1 emerges at a distance of more than 700 meters and is linked to all of the market basket sampling near the Kalpakkam shoreline. This includes all the finfish and shellfish (1) Coach whips trevally, (3) Brown stripe red snapper, (4) Japanese threadfin bream, (5) Common pony fish, (7) Striped eel catfish, (8) Snakefish, (9) Saddle grunt, (11) White cheek monocle bream, (12) Freckled goatfish, (13) Spindle croaker, (14) Fringe fin zebra sole, (15) Malabar thryssa, (17) Indian sweeper, (19) Scaly whip ray, (20) Pug nose pony fish, (21) White-spotted spine foot, (22) Flat needlefish, (23) Jarbua terapon, (24) Flathead grey mullet, (25) Indian oil sardine, (26) Indian mackerel, (27) Savalai hair tail, (28) Devis' anchovy, (29) Three spotted flounders, (31) Mustached thryssa, (32) African sea catfish, (33) Silver sillago, (35) Seven finger threadfin, (37) Longhead grunt, (38) Wavy-lined grouper, (40) Commerson's sole, (2) Giant tiger prawn, (6) Flathead lobster, (10) swimming crab, (16) Indian white prawn, (18) Crucifix crab, (30) three spot swimming crab, (34) big fin reef squid, (36) ridged swimming crab, (39) Banana prawn. Shellfish have higher radioactive activity than finfish. The intensity of pollution from natural and artificial sources from the environment is determined by the diurnal variation pattern of these indicators, with the strength representing pollution from normal and manmade sources from the environment.

Cluster 2 appears at a distance of more than 300 meters, and market basket sampling is associated with two main groupings (MBS). At a distance of 100 m, Cluster Group 3 occurs, with more significant radionuclide groups associated with market basket sampling (MBS). This association is most likely dependent on the parameters' distance levels from the market basket sampling in question; it is probable to uncover the difficult issues affecting the environmental situation near five shoreline zones.

Conclusion

India has evolved its regulations on the irradiation of food and agricultural products over time. The initial legislation was in 1991 and amended in 1996, titled Atomic Energy (Control of Irradiation of Food) Rules. The Atomic Energy Regulatory Board (AERB) supervises these rules. Amendments to the Prevention of Food Adulteration Act (1954) Rules in 1994, 1998, and 2001 allowed irradiation of various food items, including fish in domestic markets. The Food Safety & Standards Authority of India (FSSAI) in 2006 introduced new methods of radiation processing and rules under the Food Safety and Standards (Food Products Standards and Food Additives) Amendment Regulations, 2016. The Ministry of Agriculture also amended plant protection and quarantine regulations to facilitate market access. These regulations allow radiation processing of food and agro commodities based on generic food classes, with licensing facilities and approval, operation, and process control conditions.

The delivery of potassium, uranium, and thorium in Market Basket Sampling (MBS) methods were deliberate by the different age group in and around the coastal zone by ensuing the recommendations of WHO in evaluating the contaminants in the marine finfish and shellfish. This would serve as a reference point for the coastal zone. In general, shellfish have more activity than finfish in our current study. Similarly, the annual intake and ingestion dose was Below Detectable Limit in Market Basket Sampling (MBS) methods approach. However, the calculated ingested dose values, Pearson correlation, principle component, and cluster for seven distinct age groups are Par with healthy levels according ICRP limit, representative that there is no considerable radiological threat due to fish diversity in the study region.

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