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Assessment of the doses due to natural radionuclide in the green leafy vegetables of Domiasiat, Meghalaya India

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Abstract A radiation dose assessment exercise was carried out for the *Ipomea batata*, *Allium sativum, Dacaus carota,* and *Solanum tuberosum* due to naturally available radionuclide ^{40}K, ^{238}U and ^{232}Th in the Domiasiat area of Meghalaya. The concentration of radionuclides in biota as well as corresponding soil was measured by precipitation method using NaI detector for continuous 12 months. Transfer factor was calculated and was, for ^{40}K(3.96E−05, 3.40E−05, 3.40E−05, 2.70E−05), for ^{232}Th(3.94E−05, 3.20E−05, 3.20E−054.93E−05), for ^{238}U(3.60E−05, 3.89E−05, 3.85E−054.57E−05), respectively in each biota due to each radionuclide. The point source dose distribution (source ↔ target) hypotheses was applied for the consideration of absorbed fraction. The generated data were modeled using the FASSET method and obtained dose was 8.42E−03, 8.36E−03, 7.78E−03, 7.74E−03 μGy h^{-1}, respectively and finally compared with the IAEA and UNSCEAR dataset for screening level dose for terrestrial biota.

Keywords Domiasiat · *Allium sativum* · *Dacaus carota* · *Ipomea batata* · *Solanum tuberosum* · FASSET · Dose

Introduction

Radiation study in the biota including human beings is crucial to the understanding of adverse effects of radiation. Harvesting of nuclear power is increasing democratically at global level and the associated activities of harvesting impact biota adversely. The Atomic Minerals Directorate for Exploration and Research (AMDER) Government of India has reported the range of U_3O_8 from 0.061 to 0.128% with an average of 0.104% and these ore are amenable for open cast mining in (lower proterozoic) Shillong group of rocks in Domiasiat, in India [1].

Key questions that have been growing throughout the international arena and now in India as well includes why should we protect the environment, what should we protect and how can we demonstrate protection of species other than humans from the radiation? FASSET addresses through consideration of sources, exposure, dosimetry and effects on target organisms and ecosystems [2]. FASSET thus supports decision-making mechanisms for regulating approaches to protecting the environment from the effects of ionizing radiation [3]. “Over the last decade a number of models, almost 15 and approaches have been developed for the estimation of the exposure of non-human biota to ionizing radiations. In some countries these are now being used in regulatory assessments” [4]. This paper examines incorporation of radiation dose to the locally grown green leafy vegetable *Allium sativum, Dacus carota, Ipomea batata* and *Solanum tuberosum* due to the naturally available radionuclide ^{40}K, ^{238}U and ^{232}Th in Domiasiat the proposed uranium mining area which is heavily consumable by the local people. The data being generated during the pre-mining condition would form a baseline data for comparison with the post-mining scenario**.** The three naturally occurring radionuclide ^{40}K, ^{238}U and ^{232}Th are predominant in the study area [5]. Contamination of the environment by radio nuclides inevitably results in an increase in the radiation exposure of natural populations of organisms that inhibit the area (Figs. 1, 2; Table 1).

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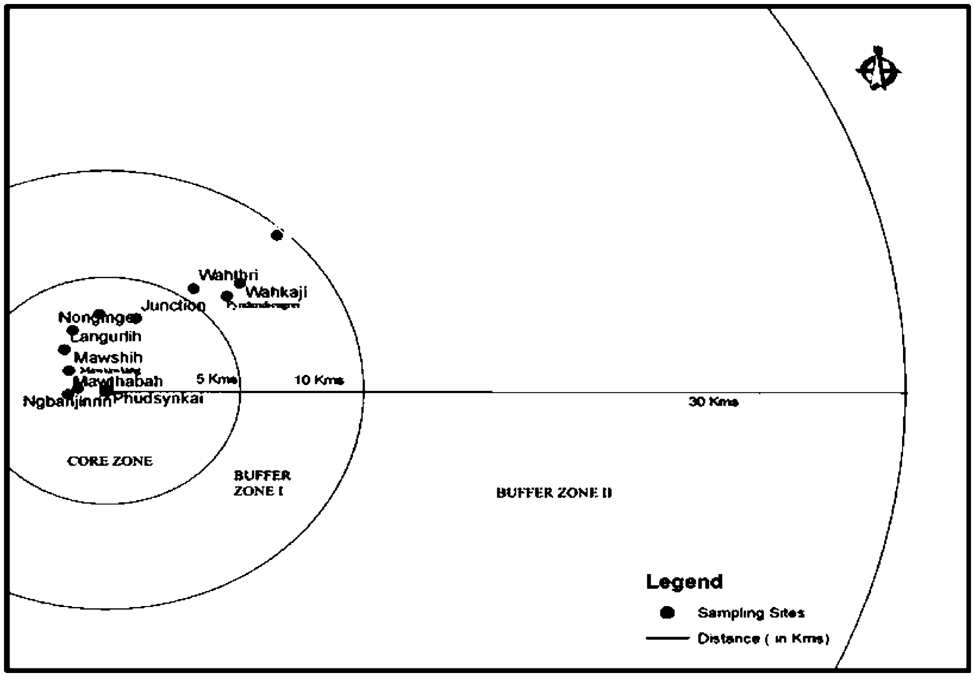

Fig. 1 The zone-wise sampling point for the biota

Fig. 2 The semi-natural disturb agriculture ecosystem

Experimental

Domiasiat is located in south western part of West Khasi Hills District Meghalaya at latitude N25°16′30″ and longitude E91°16′15″), India (Fig. 3). The sampling site is much close to Domiasiat-Mawthabah area approximately at a distance of 2–4 km and the area was identified as one which has a heavy deposit of uranium ore. Wahakaji and Umdohlum the sampling site is the scarcely populated rural area having the semi natural disturbed agriculture ecosystem and is at the periphery of the dense forest ecosystem.

Ipomea batata

The sweet potato is a vine whose large, starchy, sweet-tasting tuberous roots are an important root vegetable. Tuber and rhizomatous crops like sweet potato grow abundantly in the region [6]. Sree Gouri, a sweet potato variety released is a medium duration variety (115 days) with high carotene content (5.1 mg 100^{-1} g), can tolerate mid season stress and hence suitable for both Kharif and Rabi seasons and yields up to 30 tha^{-1}. The tuber skin is purple red (Fig. 4) with very attractive deep orange tuber flesh color [7].

Table 1 Selected biota taxonomy

Local Khasi name	Jyllang	Kajor	Phan	Phan-dieng
English Name	Garlic	Carrot	Potato	Sweet-potato
Kingdom	Plantae	Plantae	Plantae	Plantae
Order	Aspargales	Apiales	Solanales	Solanales
Family	Alliacae	Apiaceae	Solanaceae	Convolvulacae
Genus	*Allium*	*Dacus*	*Solanum*	*Ipomea*
Species	*Sativum*	*Carota*	*Tuberosum*	*Batata*
Variety	–	–	*KufriMegha1998*	*Sree Gouri*

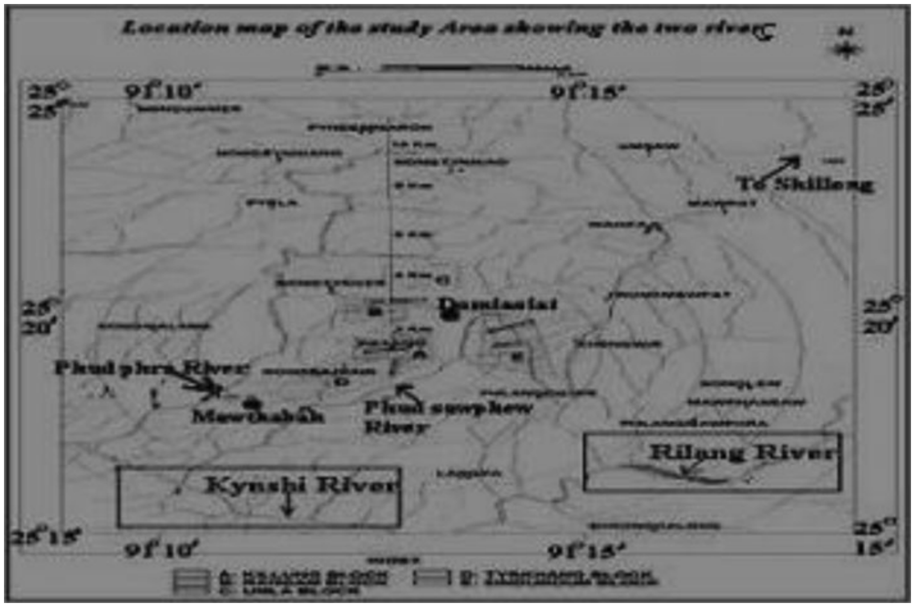

Fig. 3 Domiasiat and Kynshi River

Fig. 4 *Ipomea batata*

Solanum tuberosum

It is a rhizome grown under the highly arable and well ploughed soil. Medium late blight, Kufri Megha-1998 varieties is well cultivable and established potato crops of Meghalaya (Fig. 5) [8]. It is widely used as a vegetable and

Fig. 5 *Solanum tuberosum*

in other dishes in India; particularly in Meghalaya used as a local chip and has the potential to be main nutrient supplement if taken as a main course diet.

Dacaus carota

A conical tap root well established and cultivable vegetable species in the north-eastern Himalayan region and abundantly in the study area, of India [9]. Carrot is widely used as vegetable. The suitable part to be eaten of carrot is a taproot when it is still fresh, it has a crispy texture (Fig. 6).

Allium sativum

It is most commonly used bulb grown in the area and also taken as medicine in the local Khasi tribe for the various ailments (Fig. 7). Bulb of garlic, the most commonly used part of the plant along with scapes. *Allium sativum* mostly grown in study area as backyard farm product, mostly consumed as spices in hot curries of the different meat dishes. It has a very wide concern from the radiation accumulation point of view as study shows that at the depth of 3 cm the radiation accumulation for the mono-energetic photons emitted from a planner source is maximum and the *Allium* bulb mostly available at that depth [2].

Sampling of biota and assumptions for dose calculation using FASSET

The sampling had been done in the cultivable season of the particular vegetable species directly from the agriculture land. The soil sample were collected continuously for 12 months and analysis of variance (ANOVA) was used to

Fig. 6 *Dacus carota*

Fig. 7 *Allium sativum*

avoid the measurement error. The DPUC values for each of the selected biota species were obtained by considering them either as herbs or shrubs and assuming the target entirely exposed under the soil ecosystem and have the ellipsoidal body geometry. The calculated dose is of the chronic type by the Low LET (Liner energy transfer) in micro Grey per hour and it is of un-weighted type. As FASSET assumed that the external radiation deposition in the similar type of biota; is under the 10 cm of the soil depth (radiation source) and uniformly received radiation through foliar absorption and finally summed up in the total radiation accumulation.

Estimation of radionuclides

Sample preparation and analysis was done as per the USEPA protocol for the radionuclide measurement in flora, fauna and soil. Radionuclides concentration of ^{40}K, and ^{232}Th in biota was measured using Gamma Spectrometer (Table 2). Activity concentrations in the corresponding soil samples are also measured ("Appendix 1" section) using Gamma ray Spectrometer consisting of NaI(TI) detector

Table 2 Measured concentration calculated activity, calculated transfer factor and Obtained DPUC

Biota	Measured concentration[a]			Activity calculated (Bq kg^{-1})			Transfer factor(TF) obtained (Bq kg^{-1} per Bq m^{-2} year^{-1})[b]			DPUC$_{ext}$ (μGy h^{-1} per Bq kg^{-1})[c]			DPUC$_{int}$ (μGy h^{-1} per Bq kg^{-1})			pH of soil
	^{40}K (ppm)	^{232}Th (ppm)	^{238}U (ppb)	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U	
Ipomea batata	3488	16	3.7	112.40	0.065185	0.045222	3.96E−05	3.94E−05	3.60E−05	2.70E−05	3.50E−08	4.50E−08	2.90E−04	2.40E−03	2.30E−03	4.0–6.3
Allium sativum	5474	9.2	17.7	176.38	0.037481	0.216333	3.40E−05	3.20E−05	3.89E−05	2.90E−05	3.50E−08	4.50E−08	2.90E−04	2.40E−03	2.30E−03	
Dacus carota	3514	1.3	0.4	113.22	0.005296	0.004889	3.40E−05	3.20E−05	3.89E−05	2.90E−05	8.90E−08	9.60E−08	2.90E−04	2.40E−03	2.30E−03	
Solanum tuberosum	2370	20	4.7	76.366	0.081481	5.7E−04	2.70E−5	4.93E−05	4.57E−05	2.70E−05	3.50E−08	4.50E−08	2.90E−04	2.40E−03	2.30E−03	

[a] Kharbuli and Iongwai [14]; [b] Calculated; [c] Obtained form FASSET

housed in 7.5 cm thick lead shielding, PC coupled 8 K MCA card and associated electronics and was calibrated using HPGe (high purity germanium) detector. Minimum detection limit for 300 g of soil for ^{40}K, and ^{232}Th was 7.7, and 3.4 Bq kg^{-1}, respectively. Minimum detection limit for 100 g plant sample for ^{40}K, ^{232}Th was 0.016, and 0.008 Bq g^{-1}, respectively [10, 11]. Energy calibration and efficiency evaluation of the Gamma-Spectrometer was done by using standards obtained from IAEA in the appropriate matrix [11]. The standard were packed in similar plastic containers which were used for soil and plant samples storage and counted after allowing time for attaining secular equilibrium. Soil samples were counted for 80,000 s and plants samples were counted for 1,50,000 s. ^{40}K in the sample was evaluated from 1460.8 keV peak from a calibrated KCl standard and compared. ^{232}Th was estimated from 2614.53 keV. The details of measured average activity due to ^{40}K, ^{238}U and ^{232}Th in soil are in "Appendix 1" section. The average concentration of the three fragmented area Whakaji, Syngkai and Domiasiat (Fig. 1) were considered to minimize the sampling error and to keep uniformity during the sample collection.

Results and discussion

Calculation of transfer factor

The site specific TF values were obtained for all these three radionuclide in all the species as follow e.g. *Ipomea batata* (Table 2).

By ^{40}K

Measured concentration = 887.5 ppm
= (3488 × 0.00087 × 1000)/27 = 112.40 Bq kg^{-1}
TF = biota activity/soil activity = 112.40/283.4 = 3.96E−05
(Measured total activity in soil ^{40}K = 283.4; SD ± 98.4)

By ^{232}Th

Measured concentration = 16 ppm
= (16 × 0.065185 × 1000)/27 = 3.94E−05 Bq kg^{-1}.
TF = biota activity/soil activity = 0.015074/165.4 = 9.11E−05.
(Measured total activity in soil ^{232}Th = 165.4; SD ± 63.9).

By ^{238}U

Measured concentration = 3.7 ppb
= (3.7 × 0.00033 × 1000)/27 = 0.045222 Bq kg^{-1}
TF = biota activity/soil activity = 0.011/125.6 = 3.60E−05
(Measured total activity in soil ^{238}U = 125.6; SD ± 56.2)
Similarly for all the species transfer factor is calculated (Table 2).

Calculation of dose

External dose

The external dose is calculated by using the following equation ("Appendix 1" section) for each radionuclide separately e.g. *Ipomea batata* (Table 2).
Dose = Σ soil activity × $DPUC_{ext}$ = (283.4 × 2.70E−05 + 165.4 × 3.50E−08 + 4.50E−08 × 125.6) = 7.66 E−03 μGy h^{-1}.

Internal dose

Dose = Σ TF × $DPUC_{int.}$
= (3.96E−05 × 2.90E−04) + (3.94E−05 × 2.90E−04) + (3.60E−05 × 0.00146) = 1.17E−04 μGy h^{-1}
Total dose = external + internal
7.66E−03 + 1.17E−04 = 7.78E−03 μGy h^{-1}7.66E−03 + 1.17E−04 = 7.78E−03 μGy h^{-1}

The result shows that the obtained concentration factor (soil to plant transfer) biota was obtained and it was in the range for *Allium sativum, Dacaus carota, Ipomea batata* and *Solanum tuberosum* for ^{40}K (0.669645, 0.429874, 0.426694, 0.289927) respectively and for ^{232}Th (0.000227, 3.2E−05, 0.000394, 0.000493) and for ^{238}U (0.001722, 3.89E−05, 0.00036, 0.000457) respectively [12, 13]. The foliar absorption is the plant morphology specific and was assumed that the external radiation absorbed uniformly from the isotropic and homogeneous radiation source and quantified in total sum of measurement by internal uptake [13]. And obtained total dose was 8.42E−03, 8.36E−03, 7.78E−03, 7.74E−03 μGy h^{-1} respectively. Result also depicts that the concentration factor are in direct proportion to the received doses. The weathering of igneous rocks gives rise to ^{232}Th, ^{235}U and ^{238}U, long-lived radionuclide remaining from the primordial nucleosynthesis. Among all these four biota the maximum total doses was experienced in the *Allium sativum* while the least is in *Solanum tuberosum.* The major dose incorporation is due to the internal uptake and accumulation of the radionuclide to the tissue in all these four species. External energy deposition is comparatively low. But in case of *Allium sativum* the differences in external and internal energy deposition is found higher in comparison with the other biota. The

Table 3 Calculated external, internal and total doses (μGy h^{-1}) to cereal species due to different radionuclide

Species	Total (μGy h^{-1})	External (μGy h^{-1})			Internal (μGy h^{-1})		
		^{40}K	^{232}Th	^{238}U	^{40}K	^{232}Th	^{238}U
Ipomea batata	7.78E−03	7.65E−03	5.79E−06	5.65E−06	1.15E−04	9.46E−07	8.28E−07
Allium sativum	8.42E−03	8.22E−03	5.76E−06	5.65E−05	1.80E−04	5.44E−07	3.96E−06
Dacaus carota	8.36E−03	8.22E−03	5.79E−06	5.65E−06	1.16E−04	7.69E−08	8.95E−08
Solanum tuberosum	7.74E−03	7.65E−03	5.79E−06	5.79E−06	7.81E−05	1.18E−06	1.05E−06

overall external deposition of energy is relatively higher in the *Allium sativum* in comparison with the other three species. Among all the four species the internal energy deposition in the tissue is highest due to the ^{40}K radionuclide. Radiation accumulation due to ^{232}Th and ^{238}U externally in *Allium sativum* and *Dacaus carota* is same may be due to the same uptake pattern of low LET by these two radionuclides in the tissue as the characteristically these two radionuclides emits photon and electron in order of maximum absorbed fraction I (Table 3).

Conclusion

It could be concluded that the naturally occurring radionuclide ^{40}K, ^{232}Th and ^{238}U in the Domiasiat incorporate radiation in the form of chronic un-weighted doses to the all these four vegetable are in the ranges of 7.74E−03-8.36E−03μGy h-^{1}. The main contributor to the doses are primordial radionuclide ^{40}K. The doses received by the biota are in the range of modeled doses to the leafy vegetable by FASSET. And among all these for biota the maximum un-weighted chronic type dose was in *Allium sativum* and in the semi natural disturbed agriculture ecosystem of Domiasiat. *Allium* need to be screened for further risk assessment in post mining scenario. This is observed in the pre-mined condition and there are the fair chances of enhancement in the dose to the biota after post mining when the radionuclide will be exposed to the surface and in biosphere.

Appendix 1

Dose equation description general

$$\text{DPUC}\alpha \text{ int} = 5.77 \times 10_{-4} x\varphi\alpha \times \Sigma(piEi)\,\alpha \quad (1)$$

$$\text{DPUC}\alpha \text{ ext} = 5.77 \times 10_{-4} x\,(1-\varphi\alpha) \times \Sigma(piEi)\alpha \quad (2)$$

$$D = \Sigma(C_i\text{soil} \times \text{CF}_i\text{soil} \times \text{DPUC}_{\text{totalint}i}) + \left((f_{\text{sediment}} + 0.5 f_{\text{surface}})C_i\text{sediment} + (f_{\text{water}} \times C_{\text{iwater}})\right) \times \text{DPUC}_{\text{totalext}})i) \quad (3)$$

C_{water} and C_{sediment} are the radionuclide concentrations in water and sediment respectively; CF_{water} is the concentration factor for biota referenced to water; f_{sediment} is the fraction of time spent buried in sediment; f_{surface} the fraction of time spent on the sediment surface; and f_{water} the fraction of time spent free swimming in the water column or on the water surface.

Appendix 2

See Table 4.

Table 4 Average activity of the Whakaji and the adjacent area of three naturally occurring radionuclide

Radionuclide	Whakaji	Domiasiat	Syngkai	Average	SD
^{40}K	370.8083	191.284	288.5429	283.5453	±98.4
^{232}Th	147.3667	133.9	214.95	165.4056	±63.9
^{238}U	53.44167	70.692	252.6857	125.6066	±56.2

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