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Natural Radioactivity and Hazards Assessment in Medicinal Plants in Bangladesh

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Abstract The radioactivity concentrations of ^{238}U, ^{232}Th and ^{40}K in medicinal plants commonly used in Bangladesh were measured using High-purity Germanium gamma spectrometry. The potential radiation hazards associated with these medicinal plants were assessed by evaluating the absorbed dose rate, radium equivalent activity, external hazard index, annual effective absorbed dose and annual effective ingestion dose. The activity concentrations in the studied medicinal plants ranged from 4.12±2.46 to 28.22±7.84 Bq/kg, 3.02±1.60 to 17.62±6.48 Bq/kg and 363.0±36.4 to 1097.1±209.9 Bq/kg for ^{238}U, ^{232}Th, and ^{40}K with the mean values of 12.65±5.20, 7.38±3.45, and 661.1±202.6 Bq/kg, respectively. The average annual committed effective doses for ingestion of natural radionuclides ranged from 6.29±1.24 to 18.17±4.64 μSv with an average value of 11.46±2.57 μSv, which is far below the world average value of 285 μSv/y reported by UNSCEAR 2000. This is the first time measurement of natural radioactivity of medicinal plants in Bangladesh. The present results are, therefore, expected to provide the baseline data for settling a safety standard and guideline for the utilization of these medicinal herbs in Bangladesh.

Keywords Activity concentration, Gamma-ray spectroscopy, Medicinal plant, Radiological hazards

1. Introduction

Naturally occurring radionuclide materials (NORMs) are found to be present in significant amounts in air, soil, rocks, plants, foods, recycled industrial waste-products and also in human body [1-4]. The NORMs in the environment mostly come from the decay chains of ^{238}U and ^{232}Th, and also from ^{40}K [4-6]. Because of these natural radionuclides humans are continuously exposed to gamma radiation both externally and internally.

Plants have formed the idea of sophisticated traditional medicine systems that have been in existence for thousands of years and continuing to provide mankind with new remedies. It has been reported [7] that about 70-80% of the world populations, particularly in the developing countries, primarily depend on the nonconventional medicine in their medical procedures. Accordingly, medicinal plants are increasingly used also in Bangladesh, mainly because they are readily available and cheaper than modern medicines. Varieties of medicinal herbs are grown in Bangladesh in different seasons. NORMs and their progeny present in these medicinal plants of Bangladesh may cause health hazards for the population. The assessment of radioactivity in different medicinal plants is, therefore, of great importance and interest in health physics not only for many practical reasons but also for more fundamental scientific reasons.

The radionuclides present in the environment are transferred to the herbs through their roots from soil and through aerial parts by direct absorption. Qualitative and quantitative knowledge of the radioactivity level is important since it concerns the radionuclides liable to cause radiation protection problems under extreme conditions. Recently, plant researches have been increased significantly all over the world and the concentrations of NORMs in different medicinal plants have been measured by a number of experimental groups [8-14] to monitor radiation level in the environment. However, in Bangladesh, the systematic studies on the distribution and enrichment of radionuclides in medicinal plants are sparse. Depending upon the physiological characteristics of the plants a large variation is observed in the degree of translocation of radionuclides to herbs of different species. The measurement of natural radioactivity in medicinal herbs in Bangladesh perspective is, therefore, a significant research interest.

The purposes of this study are to report on: (i) the activity concentrations of natural radionuclides ^{238}U, ^{232}Th and ^{40}K in some selected medicinal plants in Bangladesh; (ii) the annual effective absorbed dose and the annual ingestion dose in order to evaluate the external exposure and the uptake of NORMs; and (iii) the radiological risk due to the

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consumption of the studied medicinal plants. Various techniques with different principles are available to determine the radioactivity levels in the samples. Gamma-ray spectrometry system is one of them. This technique is common to low-level radio-analysis and applicable to other environment contaminants as well. In the present study, the gamma-ray spectroscopy measurements were carried out with a high resolution HPGe detector in Health Physics Division, Atomic Energy Centre (AEC), Dhaka.

2. Materials and Methods

2.1. Sampling Area

A total of 39 samples of medicinal plants, listed in Table 1, commonly used in Bangladesh were collected during October 2017 to January 2018 from the industrial area of Kushtia district, the western part of Bangladesh under Khulna division. With an area of 1608.80 square kilometers the district is located in between latitudes 23.90°N and longitudes 89.12°E and is situated at elevation 17 m above sea level. It is bounded by Rajshahi, Natore, Pabna districts to the north, by Chuadanga and Jhenaidah districts to the south, by Rajbari district to the east, Meherpur district to the west, and an international boundary to the West Bengal of India to the west. The main rivers: Ganges (Padma), Gorai, Mathabhanga, Kaliganga and Kumar are flowing through the district. The temperature varies between 37.8°C to 9.2°C and an annual rainfall average is 1,467 millimeters.

2.2. Sample Preparation

The samples were washed with water to remove soil contamination and then dried under the sun. These samples were then crushed into small pieces, homogenized and dried again using an electric oven at 105°-110°C up to the time of achieving a constant weight. The dried samples were grounded to fine powder, meshed through 0.5 mm sieve and finally-sealed into a Marinelli beaker. Before counting, the samples were left at room temperature for about 1 month so that the radionuclides ^{226}Ra, ^{222}Rn and their daughters attain at the secular equilibrium. The present study used dry mass of the samples to determine the radionuclide concentration. Table 1 lists the name (the traditional name as well as the scientific name) and the part of the medicinal plants studied.

Figure 1. Sampling location map of Kushtia district

Table 1. Data of plant sample used in this study

Sample ID	Name of the plant sample		Part used	Sample ID	Name of the plant aample		Part used
	Traditional	Scientific			Traditional	Scientific	
SMP01	Apang	Princkly Chaff-Flower	Whole body	SMP21	Sadatil	Sesame	Seed
SMP02	Akondo	Calotropis	Leaves	SMP22	Kalijira	Black cumin	Seed
SMP03	Arjun	Arjuna	Bark	SMP23	Lobongo	Clore	Fruit
SMP04	Ulatkombol	Abroma augusta	Leaves	SMP24	Methi	Fenugreek	Seed
SMP05	Thankuni	Asiatic pennywoet	Leaves	SMP25	Amloki	Amla	Fruit
SMP06	Talecochu	Coccinia	Leaves	SMP26	Chirota	Swertia	Whole body
SMP07	Keshraj	Eclipta prostrata	Whole body	SMP27	Horitoki	Black Myrobalan	Fruit
SMP08	Bel	Bael	Fruit	SMP28	Tisi	Flax	Seed
SMP09	Asamlata	Climbing hempvine	Leaves	SMP29	Daruchini	Cinnamon	Bark
SMP10	Durba	Bermuda grass	Leaves	SMP30	Elaichi	True cardamom	Fruit
SMP11	Neem	Azadirachta	Leaves	SMP31	Helencha	Splnach	Leaves
SMP12	Gondho Vadule	Paederia	Leaves	SMP32	Jolkolmi	Water spinach	Leaves
SMP13	Mehedi	Henna	Leaves	SMP33	Akapulko	Candle bush	Leaves
SMP14	Tetul (green)	Tamarind	Fruit	SMP34	Kanshira	Benghal dayflower	Leaves
SMP15	Tetul (ripe)	Tamarind	Fruit	SMP35	Ghatecochu	Colocasia	Leaves
SMP16	Tejpata	Indian bay leaf	Leaves	SMP36	Garpata		Leaves
SMP17	Supari	Areca Nut	Fruit	SMP37	Noyontara	Rose periwinkle	Leaves
SMP18	Tulsi	Holy Basil	Leaves	SMP38	Peyara pata	Guava leaf	Leaves
SMP19	Paan	Betel leaf	Leaves	SMP39	Sojina pata	Moringa leaf	Leaves
SMP20	Holud	Turmeric	Root				

2.3. Measurements

The concentrations of the natural radionuclides in the medicinal plants were measured using a gamma-ray spectrometer associated with a coaxial ORTEC HPGe detector connected to EMCAPLUS and computer with a program installed for data acquisition and analysis of the gamma-ray spectrum. The spectrometer was calibrated using the monoenergetic gamma sources ^{137}Cs, ^{60}Co and ^{40}K as they emit gamma-ray energies over the entire energy-range of interest. The activities of ^{238}U, ^{232}Th and ^{40}K were measured from the photo-peaks of their respective daughter nuclei. The measurement time for each sample was set at 10,000 s. All measurements were corrected from background radiations by counting an identical empty beaker for the same counting time.

2.4. Calculations

We employed the following analytical expression [15] to evaluate the activity concentration A (Bq/kg) of individual radionuclide

$$A = \frac{N}{\varepsilon_\gamma \times \rho_\gamma \times T_s \times M} \quad (1)$$

Here, N, ε_γ, ρ_γ, T_s and M denote, respectively, the net counts of the photo-peak, the detector efficiency, the intensity of the gamma-ray energy, the sample counting time and the mass of the sample. Error associated with every calculation was measured by the standard deviation (SD) equation.

Once the activity concentration of natural radionuclide is obtained the absorbed dose rate D in outdoor air at 1 m above the ground surface can be calculated by [4,16]

$$D\ (nGy/h) = 0.462A_U + 0.604A_{Th} + 0.0417A_K, \quad (2)$$

where, A_U, A_{Th} and A_K represent the activity concentrations, in Bq/kg, of ^{238}U, ^{232}Th and ^{40}K, respectively.

Each of 1 Bq/Kg of ^{238}U, 0.7 Bq/Kg of ^{232}Th and 13 Bq/Kg of ^{40}K can produce an identical γ-ray dose rate [4,17]. Considering this fact, a common hazard index, known as the radium equivalent activity Ra_{eq}, was calculated by

$$Ra_{eq}\,(Bq/kg) = A_U + 1.43A_{Th} + 0.077A_K \quad (3)$$

The external hazard index H_{ex} was estimated by using the following relation [4,18]

$$H_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (4)$$

The annual effective doses E_{exp} and E_{ing} due to, respectively, the external exposure and ingestion of NORMs in the studied medicinal plants were obtained by [19-21]

$$E_{exp}\left(\frac{\mu Sv}{h}\right) = D \times OF \times CF, \quad (5)$$

and

$$E_{ing}\,(\mu Sv/h) = A \times I \times DCF. \quad (6)$$

Here, OF=4380 h/y is the occupancy factor, CF=0.7 × 10^{-3} μSv/nGy is the absorbed-to-effective dose conversion factor, DCF (4.5 × 10^{-2} μSv/Bq, 0.23 μSv/Bq and 6.2 × 10-3 μSv/Bq, respectively, for ^{238}U, ^{232}Th and ^{40}K for an adult [4,22]) is

the dose conversion factor for ingestion, and I is the consumption rate from intake of NORMs in medicinal plants. The present study used a consumption rate of 1.8 kg/year [23,24], assuming that during the treatment period a patient needs 100 ml/day of the herbal preparation or product in which the average percentage plant material is 5%.

3. Results and Discussion

The present study measured the radioactivity concentrations of NORMs in 39 different medicinal plants frequently used in Bangladesh using gamma ray spectrometer. The mean concentrations of ^{238}U, ^{232}Th and ^{40}K were computed using Eq. (1). In order to estimate the potential radiation hazards due to the consumption of these medicinal plants various hazard index and annual effective doses were also evaluated using Eqs. (2)-(6). Our results were compared with the world average values set by UNSCEAR [4] and also with the data measured in other countries. Our results and comparisons are furnished systematically in the following sub-sections.

3.1. Activity Concentrations

The dry weight average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in the medicinal plants measured in the present study are depicted in Table 2. The average activity concentrations of ^{238}U was estimated by averaging the activities of its daughter radionuclides ^{214}Pb and ^{214}Bi. For ^{232}Th, the activity concentrations have been estimated by averaging the concentrations of ^{212}Pb, ^{208}Tl and ^{228}Ac. The 1461 keV gamma activity was used to determine the concentration of ^{40}K in different samples. A wide range of activities is observed for each studied sample and radioisotope. The variations in activity concentration of NORMs among the medicinal plants may be attributed due to their radioactive mineral content and their ability to absorb particular elements [23].

In the present study, the levels of ^{238}U concentration were varied from 4.12±2.46 to 28.22±7.84 Bq/kg with an average of 12.65±5.20 Bq/kg. The highest mean concentration of this radionuclide was recorded due to the SMP36. Whereas the lowest concentration was for SMP03. The concentrations of ^{232}Th were ranged from 17.62±6.48 Bq/kg in SMP38 to 3.02±1.60 Bq/kg in SMP02. The mean concentration of this series was found to be 7.38±3.45 Bq/kg. In the case of ^{40}K concentration, the maximum was recorded as 1097.1±209.9 Bq/kg in SMP10 and the minimum as 363.0±36.4 Bq/kg in SMP24 with an average of 661.1±202.6 Bq/kg. It is worth mentioning that the present results of ^{238}U and ^{232}Th are far below the reference values of 32 and 30 Bq/kg, respectively, recommended by UNSCEAR [4] for root vegetables and fruits. However, our measured ^{40}K concentration was found to be 1.5 times the reference values of 400 Bq/kg [4]. This higher concentration of ^{40}K might have come from the unreasonable applications of potassium containing fertilizer in soil from which medicinal plants absorb potassium in different amounts according to their metabolism.

Table 2. Specific activity concentrations of NORMs in the studied medicinal plants

Sample ID	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)	Sample ID	^{238}U (Bq/kg)	^{232}Th (Bq/kg)	^{40}K (Bq/kg)
SMP01	6.38±3.94	3.99±1.55	762.5±80.8	SMP22	9.07±2.41	8.28±5.94	409.9±43.2
SMP02	7.72±1.27	3.02±1.60	395.8±42.8	SMP23	10.19±1.30	6.78±4.79	404.6±36.5
SMP03	4.12±2.46	4.94±2.41	702.8±36.6	SMP24	9.08±1.16	5.25±2.74	363.0±36.4
SMP04	7.49±0.64	5.05±2.28	924.7±54.8	SMP25	13.36±5.14	9.02±6.28	389.7±62.8
SMP05	10.55±1.34	3.96±1.31	837.3±151.3	SMP26	19.16±2.80	10.64±1.87	753.5±163.9
SMP06	8.24±1.62	3.27±1.42	932.5±92.7	SMP27	7.18±1.87	5.24±4.36	398.5±43.1
SMP07	14.28±2.16	4.81±2.43	1067.5±110.7	SMP28	8.73±3.22	3.81±1.48	400.9±38.3
SMP08	7.92±1.62	3.77±1.56	748.8±44.8	SMP29	12.68±3.09	5.74±2.12	441.7±70.0
SMP09	12.92±3.36	6.31±4.08	759.1±131.8	SMP30	11.30±2.12	4.32±2.65	459.4±64.6
SMP10	18.68±3.93	10.66±4.81	1097.1±209.9	SMP31	18.25±2.74	7.19±2.96	684.0±114.1
SMP11	13.92±3.00	10.40±5.16	957.8±85.8	SMP32	13.60±1.22	6.60±3.14	566.4±85.1
SMP12	14.52±2.32	8.44±4.76	694.0±86.8	SMP33	12.36±1.12	8.4±1.84	598.2±50.0
SMP13	14.50±1.52	7.48±1.82	640.5±83.4	SMP34	14.44±1.34	4.73±0.09	672.9±92.9
SMP14	7.86±1.78	4.66±3.46	550.4±37.8	SMP35	9.34±1.57	4.64±2.44	483.4±40.0
SMP15	9.76±2.83	3.10±1.31	563.9±40.2	SMP36	28.22±7.84	12.95±4.56	640.5±132.3
SMP16	12.51±2.94	11.36±4.22	903.7±132.5	SMP37	24.36±3.76	13.95±4.81	857.9±121.5
SMP17	8.01±3.08	6.36±3.20	596.9±47.1	SMP38	15.02±1.81	17.62±6.48	786.6±87.1
SMP18	16.22±4.56	8.88±6.31	651.4±138.8	SMP39	23.94±4.08	11.94±5.94	863.8±78.4
SMP19	16.08±4.56	9.90±5.54	823.3±88.6	Min	4.12±2.46	3.02±1.60	363.0±36.4
SMP20	12.36±3.14	12.36±7.72	571.2±68.3	Max	28.22±7.84	17.62±6.48	1097.1±209.9
SMP21	8.93±2.90	7.83±5.34	427.0±43.3	Average	12.65±5.20	7.38±3.45	661.1±202.6

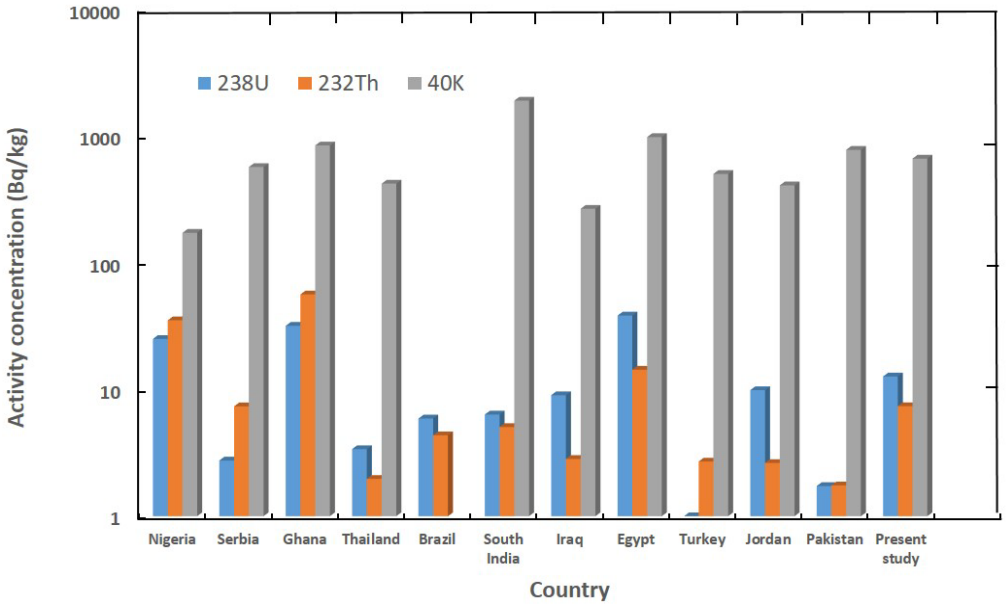

Figure 2. Comparison of mean specific activities of ^{238}U, ^{232}Th and ^{40}K in medicinal plants among different countries

As the activity concentration of any radionuclide increases with its half-life the ratio of ^{232}Th to ^{238}U in the medicinal plants should be greater than unity. But, the present study reveals up to 3 times higher concentration of ^{238}U (see Table 2) compared to that of ^{232}Th in the studied medicinal plants except in SMP03, SMP38 and SMP20. The similar results were also observed by Ferdous et al. [25] in the case of vegetables and fruit samples and by Khatun et al. [26] in the building materials.

This higher concentration of ^{238}U likely due to some rivers in the country that flow through the India containing uranium mine. For example, the river Padma flows through Bihar and the Brahmaputra, Surma and Kushiyara flow through Assam in India. In both of these places there are uranium deposit that might be carried as trace elements with the water of these rivers. These traces of uranium may easily elevate the ^{238}U to higher level in Bangladesh.

The present study results of activity concentration were compared with the reported data [10,11,14,23,27-33] for selected medicinal plants available in literature, and are depicted in Figure 2. It is evident from this comparison that the present results agree reasonably with those measured in other countries. However, the present results of ^{238}U concentration are much higher than those obtained in Turkey [31], Pakistan [33], Serbia [14] and Thailand [27], and lower than those of Egypt [30], Ghana [23] and Nigeria [10]. The lower values of ^{232}Th than the present results were reported by Pakistan [33], Thailand [27], Jordan [32], Turkey [31] and Iraq [29], and the higher values again by the Egypt [30], Ghana [23] and Nigeria [10]. In the case of ^{40}K, our result is significantly higher than those measured in Nigeria [10] and Iraq [29], and lower than those in South India [11]. The origins of the raw materials might attribute to the variation in natural radioactivity concentration among the different countries.

3.2. Hazard Indices and Annual Effective Doses

Various hazard indices and annual effective doses computed by using Eqs. (2)-(6) are presented in Table 3. Observably, the distribution of NORMs in the environmental samples including medicinal plants are not uniform. The index namely radium-equivalent activity Ra_{eq} has, therefore, been introduced to assess the radiological hazards from these non-uniform radionuclides. As shown in Table 3, the values of Ra_{eq} obtained in this study varied from 42.52±6.85 and 118.40±26.90 Bq/kg with the mean values of 74.10±13.92 Bq/kg. One can see that the present results of Ra_{eq} for all the studied samples are much lower than 370 Bq/kg recommended by the UNSCEAR [4].

The external hazard index H_{ex} characterizes the environmental samples that will provide effective dose to a permissible level. In order to limit the annual effective dose to ≤1.5 mSv the UNSCEAR [4] noticed that the value of H_{ex} must be 1. Table 3 shows that the H_{ex} values in this work were ranged from 0.115±0.019 to 0.320±0.073 with an average value of 0.200±0.038, all of which are much less than unity.

A major part of the gamma radiation comes from terrestrial radionuclides. And the terrestrial gamma radiation is directly related with the radionuclide concentrations. The UNSCEAR has recommended that the average exposure rate of the population should be within 84 nGy/h. In the present study, the calculated terrestrial gamma dose rates D ranged between 21.90±3.34 and 60.82±13.44 nGy/h with the mean value of 37.87±6.73 nGy/h. These values are lower than the maximum permissible limit.

The workers in medicinal herb stores are externally exposed to radiation due to NORMs present in the herbs. The external and internal exposures to natural radiation can be studied by knowing the annual effective doses. Two such

effective doses E_{exp} and E_{ing} due to both the exposure and ingestion of natural radionuclides in the studied samples were calculated (Table 3). The results show that the total annual effective exposure dose ranged from 67.13±10.23 to 186.47±41.20 μSv having an average value of 116.10±20.63 μSv. The annual effective ingestion dose, on the other hand, varied from 6.29±1.24 to 18.17±4.64 μSv with the mean value of 11.46±2.57 μSv. All these values are far below the reference values [4] of 410 and 285 μSv, respectively, for the exposure and ingestion of NORMs.

Table 3. Hazard indices and annual effective doses due to the NORMs in the studies medicinal plants

Sample ID	Ra_{eq} (Bq/kg)	H_{ex}	D (nGy/h)	Annual effective dose (μSv) due to	
				External exposure	Ingestion of NORMs
SMP01	70.80±12.38	0.191±0.033	37.15±6.13	113.91±18.78	10.68±1.86
SMP02	42.52±6.85	0.115±0.019	21.90±3.34	67.13±10.23	6.29±1.24
SMP03	65.29±8.72	0.176±0.024	34.19±4.12	104.83±12.62	10.22±1.60
SMP04	85.92±8.12	0.232±0.022	45.07±3.96	138.19±12.14	13.02±1.61
SMP05	80.68±14.84	0.218±0.040	42.18±7.71	129.33±23.63	11.84±2.34
SMP06	84.73±10.79	0.229±0.029	44.67±5.47	136.96±16.77	12.43±1.75
SMP07	103.37±14.10	0.279±0.038	54.02±7.05	165.64±21.62	15.06±2.41
SMP08	70.97±7.30	0.192±0.020	37.16±3.56	113.93±10.91	10.56±1.28
SMP09	80.40±19.28	0.217±0.052	41.44±9.48	127.05±29.06	12.13±3.42
SMP10	118.40±26.90	0.320±0.073	60.82±13.44	186.47±41.20	18.17±4.64
SMP11	102.54±16.99	0.277±0.046	52.65±8.08	161.43±24.77	16.12±3.34
SMP12	80.03±15.81	0.216±0.043	40.75±7.57	124.94±23.20	12.42±3.13
SMP13	74.53±10.54	0.201±0.028	37.93±5.28	116.29±16.18	11.42±1.81
SMP14	56.92±9.64	0.154±0.026	29.40±4.49	90.15±13.77	8.71±2.00
SMP15	57.61±7.80	0.156±0.021	29.89±3.77	91.65±11.57	8.37±1.22
SMP16	98.35±19.14	0.266±0.052	50.33±9.41	154.31±28.86	15.80±3.46
SMP17	63.05±11.28	0.170±0.030	32.43±5.32	99.42±16.31	9.94±2.10
SMP18	79.08±24.21	0.214±0.065	40.02±11.67	122.71±35.79	12.26±4.52
SMP19	93.63±19.30	0.253±0.052	47.74±9.15	146.37±28.04	14.59±3.65
SMP20	74.02±19.44	0.200±0.052	36.99±8.96	113.42±27.47	12.49±4.21
SMP21	53.01±13.87	0.143±0.037	26.66±6.37	81.75±19.54	8.73±2.93
SMP22	52.49±14.23	0.142±0.038	26.29±6.50	80.61±19.94	8.74±3.14
SMP23	51.05±10.96	0.138±0.030	25.68±5.02	78.73±15.38	8.15±2.50
SMP24	44.54±7.88	0.120±0.021	22.50±3.71	69.00±11.37	6.96±1.63
SMP25	56.28±18.96	0.152±0.051	27.88±8.79	85.48±26.94	9.17±3.72
SMP26	92.42±18.03	0.250±0.049	46.71±9.22	143.21±28.27	14.37±2.82
SMP27	45.36±11.43	0.122±0.031	23.10±5.30	70.82±16.24	7.20±2.44
SMP28	45.06±8.29	0.122±0.022	23.06±3.98	70.69±12.20	6.76±1.30
SMP29	54.91±11.51	0.148±0.031	27.75±5.63	85.08±17.26	8.34±1.91
SMP30	52.86±10.89	0.143±0.029	26.99±5.28	82.76±16.17	7.83±1.99
SMP31	81.20±15.75	0.219±0.043	41.30±7.81	126.62±23.94	12.09±2.72
SMP32	66.66±12.26	0.180±0.033	33.89±6.01	103.92±18.42	10.16±2.35
SMP33	70.43±7.60	0.190±0.021	35.73±3.71	109.54±11.39	11.15±1.41
SMP34	73.02±8.63	0.197±0.023	37.59±4.55	115.25±13.95	10.64±1.18
SMP35	53.20±8.14	0.144±0.022	27.28±3.87	83.63±11.85	8.07±1.58
SMP36	96.06±24.52	0.259±0.066	47.57±11.88	145.85±36.43	14.80±4.00
SMP37	110.37±19.99	0.298±0.054	55.46±9.71	170.03±29.76	17.32±3.65
SMP38	100.79±17.79	0.272±0.048	50.38±8.38	154.47±25.70	17.29±3.80
SMP39	107.54±18.61	0.290±0.050	54.30±8.74	166.48±26.80	16.53±3.66
Min	42.52±6.85	0.115±0.019	21.90±3.34	67.13±10.23	6.29±1.24
Max	118.40±26.90	0.320±0.073	60.82±13.44	186.47±41.20	18.17±4.64
Average	74.10±13.92	0.200±0.038	37.87±6.73	116.10±20.63	11.46±2.57
UNSCEAR [4]	370	1	84	410	285

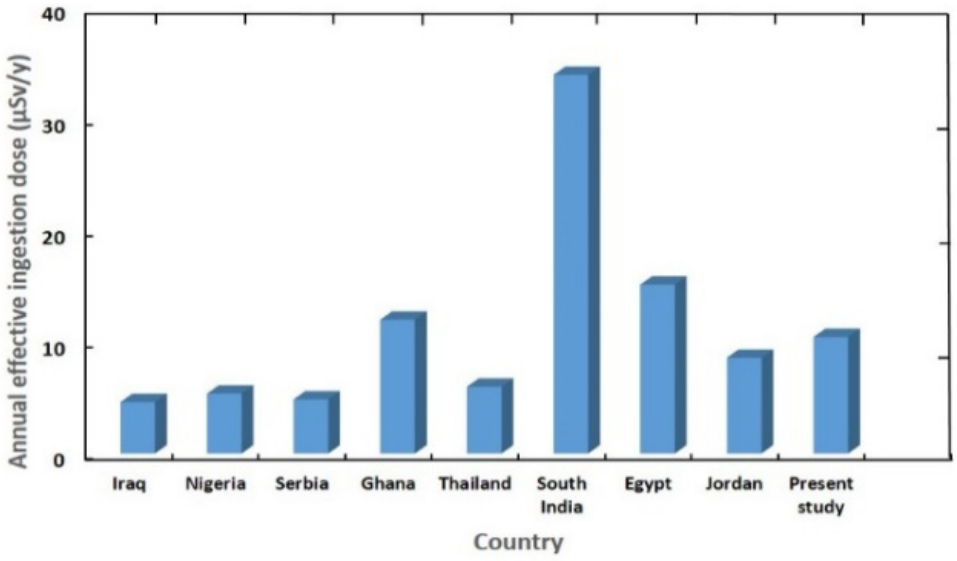

Figure 3. Comparison of the annual effective ingestion dose with the reported series

Figure 3 depicts the comparison of our annual effective ingestion dose with those estimated in Iraq [29], Nigeria [10], South India [11], Serbia [14], Ghana [23], Thailand [27], Egypt [30] and Jordan [32]. The comparison shows that our result is significantly lower than the values obtained in Iraq, Serbia, Nigeria and Thailand. The values of annual effective ingestion dose higher than the present result are found for South India and Egypt. Albeit, all of these values are much lower than the global dose [4].

4. Conclusions

An analysis of gamma rays emitting natural radionuclides i.e. ^{238}U, ^{232}Th and ^{40}K in 39 medicinal plant samples frequently used in Bangladesh was performed using gamma-ray spectrometry. Though the elemental profile of some medicinal plants with vegetables of Bangladesh has been studied earlier, the activity concentration of the naturally occurring radionuclides in medicinal plant samples has been studied for the first time. The activity concentrations in the studied medicinal plants ranged from 4.12±2.46 to 28.22±7.84 Bq/kg, 3.02±1.60 to 17.62±6.48 Bq/kg and 363.0±36.4 to 1097.1±209.9 Bq/kg for ^{238}U, ^{232}Th, and ^{40}K with the average value of 12.65±5.20, 7.38±3.45, and 661.1±202.6 Bq/kg, respectively. The mean annual effective doses due to both external exposure and ingestion of NORMs in the studied medicinal plants were found to be 116.10±20.63 and 11.46±2.57 μSv respectively. The present results were compared with their respective reference values as well as with those measured in other countries. The comparison showed that, in general, the radioactivity concentrations and their associated annual effective doses obtained in the present study were comparable with those of similar studies in other countries. The values were also found to be within the permissible limit recommended by UNSCEAR. The utilization of these medicinal plants in herbal treatment may, therefore, not produce any health hazard. The baseline data of the present study may be helpful, in future, to estimate the external and internal radiation hazards for the sake of human health.

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