ISSN: 1394-7990
Malaysian Journal of Soil Science Vol. 18: 61-74 (2014) Malaysian Society of Soil Science

Transfer of Natural Radionuclides from Soil to Plants in North Western Parts of Dhaka

Gaffar, S.[1], M. J. Ferdous[2*], A. Begum[2] and S.M. Ullah[1]

[1]*Department of Soil Water and Environment, University of Dhaka, Dhaka-1000, Bangladesh.*
[2]*Health Physics Division, Atomic Energy Centre, Shahbagh, Dhaka-1000. Bangladesh.*

ABSTRACT

The radioactivity of environmental samples from sites and suspected of contamination must be analyzed before free access is given to the public. Towards this end, plant and corresponding soil samples were collected from two different locations of North- western parts of Dhaka (Savar and Manikganj) and the activity concentrations of natural radionuclides ^{226}Ra (^{238}U-chain), ^{228}Ra (^{232}Th-chain) and non-chained ^{40}K were measured using gamma ray spectrometry. Soils of Savar contained more radioactive ^{40}K than Manikganj whereas soils of Manikganj contained more ^{226}Ra and ^{228}Ra than Savar. The influence of certain soil properties on the activity concentrations and transfer factors (TF) of natural radionuclides were investigated by correlating the observed data with those of soil properties. The activity concentrations of ^{40}K were much higher than those of ^{226}Ra and ^{228}Ra in plants for both locations due to higher uptake from soils. The transfer factors for ^{226}Ra, ^{228}Ra and ^{40}K were found to range from 0.082 to 0.926, 0.153 to 0.563 and 1.274 to 3.741 at Savar and 0.087 to 0.455, 0.061 to 0.806 and 0.738 to 1.949 at Manikganj, respectively. The soil to plant transfer factors for ^{40}K was found to be much higher in plants, which might be due to the essentiality of this element in plants. Our study showed that activity concentrations of these radionuclides in plants and their plant transfer factors seem to depend on the activity concentrations of the same radionuclides in soil.

Keywords: Activity concentrations, plants, soil, soil parameters, transfer factors

INTRODUCTION

Soil-plant-man is recognized as a major pathway for the transfer of radionuclides to human beings [(Safety Series, No. 57 (IAEA 1982)]. The radioactivity of environmental samples from sites and products suspected of contamination must be investigated before free access to them is given to the public (Owono 2010). Radionuclides in soils are frequently transferred to different plant tissues by direct transfer via the root system, or by fallout of radionuclides and resuspension of contaminated soil followed by deposition on plant leaves (Noordijk *et al*. 1992). The uptake of radionuclides from soil to plant is characterized by the transfer

*Corresponding author : E-mail: ferdous28@yahoo.com

factor (TF): the ratio of radionuclide concentration in plant to soil per unit mass (Staven *et al*. 2003; Yassine *et al.* 2003). The TF is usually used for assessing the impact of radionuclide releases into the environment. Due to a predicted long-term transfer of radionuclides in the environment, knowledge of the geochemical and ecological cycles is also needed as they relate to the behaviour of not only radionuclides but also associated elements. In general, transfer factors show a wide range of variations depending upon several factors including soil properties such as pH, clay mineral, Ca, K and organic matter content, species of plants and other environmental conditions [(TRS No. 310 (IAEA, 1990)].

As countries in the South Asian region like Bangladesh expand applications of nuclear technology, the TFs of the radionuclides in soil to the crops are viewed as one of the most significant parameters in environmental safety estimation of nuclear facilities (Chibowski 2000). Over the years, some work on the transfer or pathway mechanism of naturally occurring radionuclides to plants and human population have been reported but data are still very sparse in this area especially in Bangladesh. Not all soils have the same amount of natural radionuclides present. Therefore, the uptake in plants also varies which in turn results in different public dose rates. The aim of the present investigation was to measure activity concentrations of naturally occurring radionuclides deposited in the soil and plant and to determine soil-to-plant TF of ^{226}Ra, ^{228}Ra and ^{40}K of some plants consumed as staple by the populations in the North-western parts of Dhaka, mainly Savar and Manikganj. An investigation of this nature is useful for both the assessment of public dose rates and the performance of epidemiological studies. Also, maintaining reference-data records will assist in ascertaining possible changes in environmental radioactivity due to nuclear, industrial, and other human activities.

MATERIALS AND METHODS

Sample Collection

Two sampling sites were selected in the North-western part of Dhaka for the collection of plant and soil samples. *Figure 1* shows the sampling sites of Savar (latitude 23°58'N and longitude 90°20' E) and Manikganj (latitude 23°52' N and longitude 90°06'E). Plants commonly grown and consumed were collected in the harvesting season. To ensure sufficient representation of each area, five plants from the different sampling sites of both Savar and Manikganj were collected. Crops from Savar included red amaranthus (*Amaranthus tricolor*; S_1), elephant's ear (*Colocasia esculenta*; S_2), bitter ground (*Momordica charantia*; S_3), bind weed (*Ipomoea aquatic*; S_4) and snake gourd (*Trichosanthes anguina*; S_5). Crops from Manikganj included jute leaf (*Corchorus capsulrais*; M_1), green amaranthus (*Amaranthus lividus*; M_2), pumpkin (*Cucurbita maxima*; M_3), pumpkin leaf (*Cucurbita maxima*, M_4) and wax gourd (*Benincasa hispida*, M_5). About 5-7 kg (on fresh weight basis) of edible parts of the plants was collected. Approximately 1 kg of soil surrounding the roots of corresponding plants was collected at a depth of 0 to 15 centimeters (cm) from each sampling site in both Savar and Manikganj.

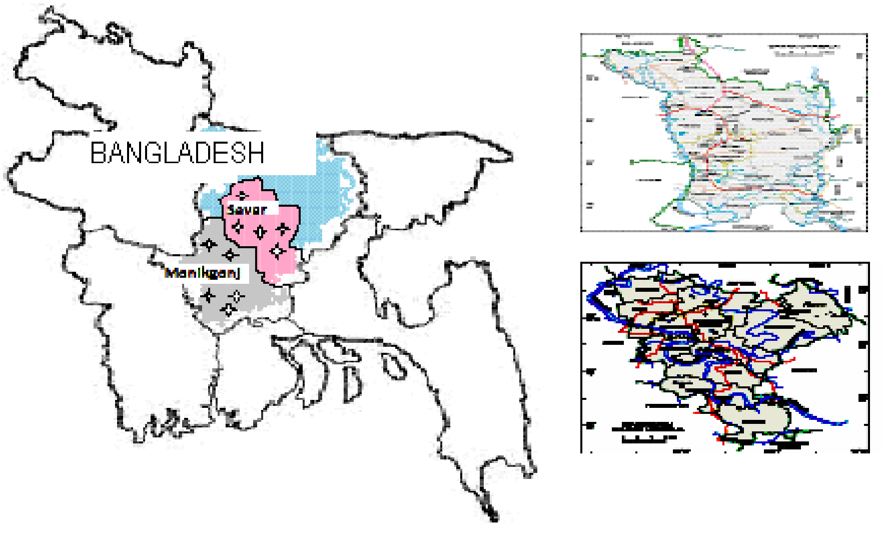

Figure 1: Map showing sampling sites at Savar and Manikganj

Sample Preparation

Plant samples were cut into small pieces and primarily dried in air by spreading on separate sheets of brown paper. The samples were then dried in an electric oven at 70 ºC until friable stage. Then the samples were ground to powder by a grinder. Each of the collected soil samples were dried in the air by spreading on separate sheets of paper after it was transported to the laboratory. After air drying, the larger aggregates were broken by gentle crushing with a hammer. The soil samples were then dried in an electric oven at 105 ºC and sieved through a 2 mm sieve. The properties of soil were determined by standard methods. Some selected physicochemical properties of soils of Savar and Manikganj are presented in Table 1. Each of the plant and soil samples was transferred to cylindrical plastic-containers of approximately equal size and shape. In order to maximize counting efficiency and precision and to minimize self-absorption for that specific geometry, containers of similar size and shape were used. The containers were then sealed tightly, wrapped with thick vinyl tapes around their screw necks, and stored for at least four weeks to reach equilibrium between the ^{238}U (^{226}Ra) and ^{232}Th (^{228}Ra) their respective progenies prior to measurement (Kabir *et al.* 2009).

Radioactivity Measurements

Radioactivity in soil and plant samples was measured by gamma ray spectrometry system. The gamma ray spectrometry system consists of a High Purity Germanium (HPGe) detector, a detector shield (lead and steel), a preamplifier, a linear amplifier, high voltage power supply, a multichannel analyzer system and a printer. The mass of the samples varied because of the varying density of the sample material but the counting time was 5000 s for each sample. Direct determination of ^{226}Ra and ^{228}Ra in the samples without any chemical treatment

TABLE 1
Selected physicochemical properties of soils of Savar and Manikganj

Parameter	pH (H_2O)	CEC (meq/100g)	Organic matter (%)	Particle size distribution (%)			Exchangeable nutrients (meq/100g)	
Sample				Sand	Silt	Clay	Ca	K
Savar								
S_1	7.04	2.24	1.93	30.02	55.58	14.4	2.32	0.1598
S_2	7.07	2.49	1.37	14.71	65.81	19.49	2.8	0.1023
S_3	6.78	2.09	2.33	16.69	61.14	22.17	1.28	0.0691
S_4	7.81	1.36	1.13	14.41	66.03	19.56	2.24	0.0639
S_5	5.21	1.98	1.61	14.66	68.38	16.96	1.2	0.0614
Average	6.78	2.03	1.67	18.09	63.39	18.52	1.97	0.0913
Manikganj								
M_1	4.95	5.18	2.89	7.97	56.72	35.32	2.32	0.0754
M_2	6.17	3.01	2.74	4.1	58.53	37.39	1.36	0.0665
M_3	5.53	3.01	2.82	2.76	56.75	40.49	1.6	0.0818
M_4	5.53	3.01	2.82	2.76	56.75	40.49	1.6	0.0818
M_5	5.99	4.78	2.66	5.78	59.05	35.17	1.76	0.0754
Average	5.63	3.79	2.79	4.67	57.56	37.77	1.73	0.076

using semiconductor γ-ray spectrometer is difficult because radionuclides do not emit any intensive γ-rays (lines) of their own. But they have several progenies which have more intensive lines and activities equal to their parents in the state of equilibrium (Bunzl and Trautmannsheimer 1999). As a result, the measurements of the radionuclides relied on detecting emissions from their progenies. The radioactivity concentration of ^{226}Ra was determined from γ-ray energies of its daughter ^{214}Bi (609.31 keV) while the ^{228}Ra was determined from γ-ray energies of its daughter ^{228}Ac (911.07 keV). The radioactivity concentration of ^{40}K was determined from the γ-ray energy of 1460.80 keV. The efficiency calibration of the detector was performed by using standard sources and the geometry of the counting samples was the same as that of the standard samples. Having established the efficiency curve, the measurements of radioactivity in plant and soil samples were carried out. Prior to sample counting, two background counts (owing to naturally occurring radionuclides in the environment around the detector) were taken twice during weekends for 5000 s each, and the average of this background was then subtracted from the samples counted during that week. Having determined the integral counts under the interested gamma-energy peaks, the gamma activity was calculated based on the measured efficiency of the detector from the following equation (Sheppard and Evenden 1988):

$$A = \frac{C}{\varepsilon(E) \times P\gamma(E) \times W}$$

where, A is the activity in Bq/kg; C is the net gamma counting rate in count per second (cps); ε(E) is the efficiency of the detector at energy E (keV); Pγ is the photon emission probability at energy E (keV) intensity of the radionuclide and W is the dry mass of the sample.

Transfer Factors

The soil-to-plant transfer factor (TF) of radionuclides was calculated as the ratio of the activity concentration in the edible part of the plant (in Bq/kg dry weight) to the activity concentration in the soil (in Bq/kg dry weight) according to the equation (Noordijk *et al.* 1992):

$$TF = \frac{Activity\ concentration\ in\ plant\ (Bq/kg\ dry\ weight\ of\ plant)}{Activity\ concentration\ in\ soil\ (Bq/kg\ dry\ weight\ of\ soil)}$$

RESULTS AND DISCUSSION

Radioactivity Concentration of ^{226}Ra, ^{228}Ra and ^{40}K

The activity concentrations of ^{226}Ra (^{238}U Chain) for soils of Savar were found to be within the range of 21±7 to 26±6 Bq/kg (Table 2).The average value for ^{226}Ra of soils of Savar was found 24±2 Bq/kg which is within the range of the world average of 35 Bq/kg (UNSCEAR 2000). The average activity concentration of ^{228}Ra (^{232}Th Chain) in soils from Savar was 41±4 Bq/kg with a range of 37±2 to 46±6 Bq/kg. Few soils contained relatively high levels of ^{228}Ra compared to the world average value of 40 Bq/kg (UNSCEAR 2000). The radioactivity concentration of ^{40}K (non-chained) ranged from 369±38 to 483±42 Bq/kg with an average value of 408±40 Bq/kg which is close to the world average of 400 Bq/kg (UNSCEAR 2000). Radioactivity of ^{226}Ra, ^{228}Ra and ^{40}K was also measured in edible parts of plants corresponding to the soils collected from Savar, Dhaka. Results revealed that the concentration of ^{226}Ra in the vegetable samples varied between 2±1 and 19±14 Bq/kg with an average value of 9±7 Bq/kg. The maximum activity was found in *Colocasia esculenta* (19±14 Bq/kg, S_2) and minimum ^{226}Ra was found in *Momordica charantia* (2±1 Bq/kg, S_3). The activity of ^{228}Ra ranged from 7±4 to 22±16 Bq/kg with an average value of 16±6 Bq/kg. The activity concentrations of ^{228}Ra in vegetables were comparatively higher than those of ^{226}Ra. *Ipomoea aquatic* (22±16 Bq/kg, S_4) and Momordica charantia (7±4 Bq/kg, S_3) were the highest and lowest accumulator of ^{228}Ra, respectively (Table 2). Activity concentrations of ^{40}K varied widely depending on plant type. Concentration of ^{40}K in plants ranged from 503±95 to 1528±145 Bq/kg with an average value of 917±445 Bq/kg. The activity concentrations of ^{40}K were found to be high in all plants. *Colocasia esculenta* was the highest (1528±145 Bq/kg, S_2) accumulator of ^{40}K. Among the investigated radionuclides, ^{40}K was found to accumulate in large amounts in different vegetables. This higher activity of ^{40}K might be attributed to the higher biological requirement of plants for potassium as it is a major essential nutrient element. Minimum ^{40}K concentration was found in *Ipomoea aquatic* (503±95 Bq/kg, S_4).

The activity concentrations of ^{226}Ra (^{238}U Chain) for soils of Manikganj were 22±5 to 30±5 Bq/kg (Table 3). The average value for ^{226}Ra in soils was found to be 26±3 Bq/kg which is within the range of the world average value of 35 Bq/kg (UNSCEAR 2000). The average activity of ^{228}Ra (^{232}Th chain) of

TABLE 2

Activity concentration of natural radionuclides in vegetable and corresponding soil samples and transfer factors from Savar, Dhaka

Sample Code	Activity concentration in plants (Bq/kg)			Activity concentration in soil (Bq/kg)			Transfer factor (TF)		
	^{226}Ra	^{228}Ra	^{40}K	^{226}Ra	^{228}Ra	^{40}K	^{226}Ra	^{228}Ra	^{40}K
Amaranthus tricolor (S_1)	6±4	21±13	1243±84	25±7	37±8	483±42	0.235	0.563	2.572
Colocasiaesculenta(S_2)	19±14	13±12	1528±145	21±7	37±2	408±35	0.926	0.348	3.741
Momordicacharantia(S_3)	2±1	7±4	712±69	25±7	43±6	386±38	0.082	0.153	1.847
Ipomoea aquatic (S_4)	11±4	22±16	503±95	23±4	46±6	395±40	0.477	0.475	1.274
Trichosanthesanguina(S_5)	8±9	16±18	600±65	26±6	41±4	369±38	0.299	0.399	1.625
Average	9±7	16±6	917±445	24±2	41±4	408±40	0.404	0.388	1.625

TABLE 3
Activity concentration of natural radionuclides in vegetable and corresponding soil samples and transfer factors from Manikganj, Dhaka

Sample Code	Activity concentration in plant (Bq/kg)			Activity concentration in soil (Bq/kg)			Transfer factor (TF)		
	^{226}Ra	^{228}Ra	^{40}K	^{226}Ra	^{228}Ra	^{40}K	^{226}Ra	^{228}Ra	^{40}K
Corchoruscapsulrais(M_1)	13±10	33±37	320±109	29±2	41±5	433±42	0.455	0.806	0.738
Amaranthuslividus(M_2)	8±3	29±36	738±103	22±5	42±7	411±41	0.343	0.697	1.794
Cucurbita maxima (M_3)	5±3	3±0.3	678±63	30±5	43±3	452±41	0.159	0.061	1.501
Cucurbita maxima (Leaf) (M_4)	4±3	4±7	706±85	23±4	34±5	366±32	0.189	0.119	1.929
Benincasahispida(M_5)	2±1	16±21	701±86	26±6	39±7	360±36	0.087	0.417	1.949
Average	6±4	17±14	628±174	26±3	40±3	404±40	0.247	0.42	1.582

soils from Manikganj was found to be 40±3 Bq/kg with a range of 34±5 to 43±3 Bq/kg. The radioactivity of ^{40}K (non-chained) ranged from 360±36 to 452±1 Bq/kg with an average value of 404±40 Bq/kg which is very close to the world average value of 400 Bq/kg (UNSCEAR 2000). Results show that activity of investigated radioactive elements varied in their activity depending on plant types. The concentration of ^{226}Ra in the vegetable samples ranged from 2±1 to 13±10 Bq/kg with an average value of 6±4 Bq/kg. The maximum value was found in *Corchorus capsulrais* (13±10 Bq/kg, M_1) and minimum value of ^{226}Ra was found in *Benincasa hispida* (2±1 Bq/kg, M_5). The activity of ^{228}Ra in plants ranged from 3±0.3 to 33±37 Bq/kg with an average of 17±14 Bq/kg. ^{228}Ra activity in vegetables was comparatively higher than that of $_{226}Ra$. *Corchorus capsulrais* (33±37 Bq/kg, M_1) and *Cucurbita maxima* (3±0.3 Bq/kg, M_3) were the highest and the lowest accumulator of ^{228}Ra, respectively. Like in Savar, ^{40}K were also high in plants of Manikganj. ^{40}K concentration ranged from 320±109 to 738±103 Bq/kg with an average value of 628±174 Bq/kg (Table 3). The activity of ^{40}K was found to be relatively high in all samples. *Amaranthus lividus* was the highest (738±103 Bq/kg, M_2) accumulator of ^{40}K. Minimum value of ^{40}K was found in *Corchorus capsulrais* (320±109 Bq/kg, M_1).

Figure 2 shows that the activity of ^{228}Ra (^{232}Th chain) was higher than that of ^{226}Ra (^{238}U Chain) in soils of Savar and Manikgonj, which is evident from the fact that Thorium is 1.5 times higher than that of Uranium in the Earth's crust (Kabir *et al*. 2009). It was also observed that the measured activity of ^{40}K (non-chained) markedly exceeded the values of both ^{228}Ra and ^{226}Ra as it is the most abundant radioactive element present in the environment. It can be seen from *Figure 4* that ^{40}K activity in plants was much higher than the activity of ^{226}Ra and ^{228}Ra in Savar and Manikgonj. This high accumulation may be due to higher biological requirements of ^{40}K; also plants have the tendency to take up soluble potassium far in excess of their needs if sufficiently large quantities are present, termed as luxury consumption (Brady and Weil 2002). Radioactive potassium is also taken along with non-radioactive potassium. Hence, the activity of ^{40}K in vegetables tested was very much higher than that in soils.

Transfer Factor (TF) of the Radionuclides in Different Plants of Savar and Manikgonj

The TF of ^{226}Ra of plants collected in Savar ranged from 0.082 to 0.926 with an average of 0.404. The highest and the lowest TF of ^{226}Ra was found in *Colocasia esculenta* (0.926, S_2) and *Momordica charantia* (0.082, S_3). The results of ^{228}Ra showed that the TF of ^{228}Ra in different plants collected from Savar ranged from 0.153 to 0.563 with an average of 0.388. *Amaranthus tricolor* (0.563, S_1) showed the highest value while the lowest value was found in *Momordica charantia* (0.0153, S_3). The TF of ^{40}K in different plants of Savar ranged from 1.274 to 3.741 with an average of 2.212. *Ipomoea aquatic* (1.274, S_4) showed the lowest TF whileas *Colocasia esculenta* had the highest TF (3.741, S_2) (Table 2).

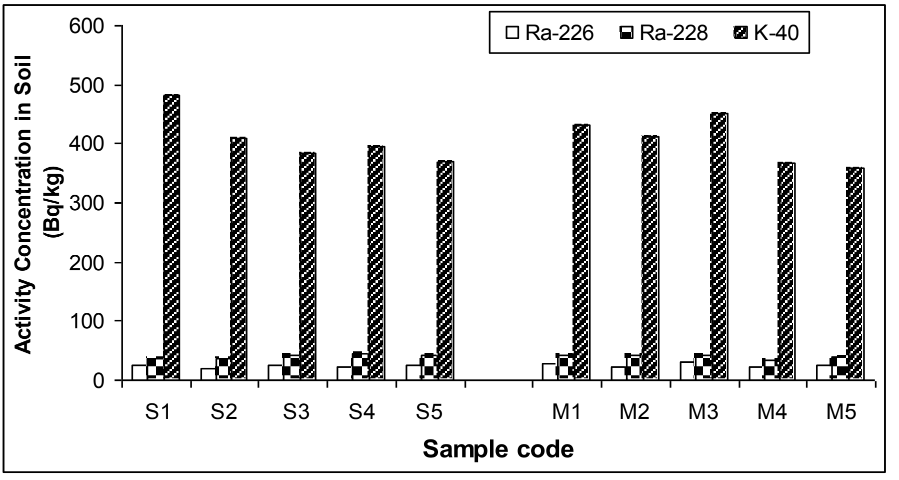

Figure 2: Activity concentration of natural radionuclides in soils of Savar and Manikgonj, Dhaka.

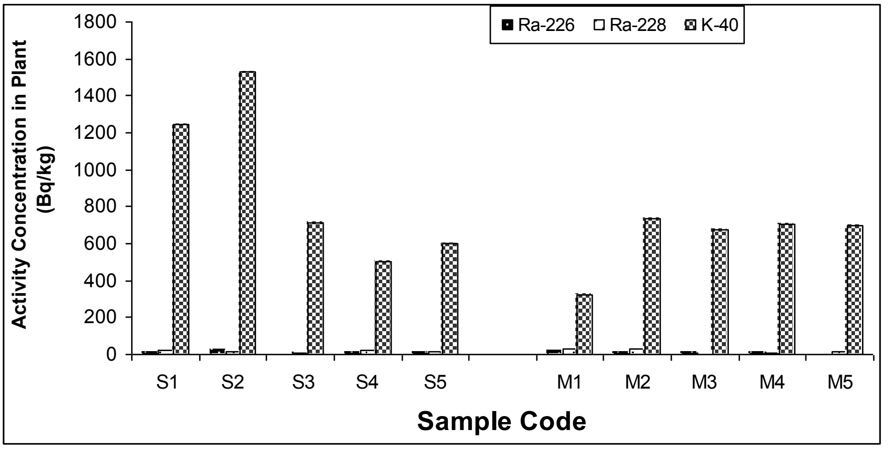

Figure 3: Activity concentration of natural radionuclides in plants of Savar and Manikgonj, Dhaka.

In Manikganj, the TFs of ^{226}Ra in different vegetable samples varied between 0.087 (*Benincasa hispida,* M_5) to 0.455 (*Corchorus capsulrais*, M_1). The average value was found to be 0.247. The TF of ^{228}Ra ranged from 0.061 to 0.806 with an average of 0.42. *Corchorus capsulrais* showed the highest TFs for ^{226}Ra and ^{228}Ra at 0.455 and 0.806, M_1, respectively, while the lowest values were found in *Benincasa hispida* (0.087, M_5) and *Cucurbita maxima* (0.061, M_3) for ^{226}Ra and ^{228}Ra, respectively. The TFs of ^{40}K ranged from 0.738 to 1.949 with an average of 1.582. Corchorus capsulrais (0.738, M_1) showed the lowest TF whereas *Benincasa hispida* had the highest TF (1.949, M_5) (Table 3).

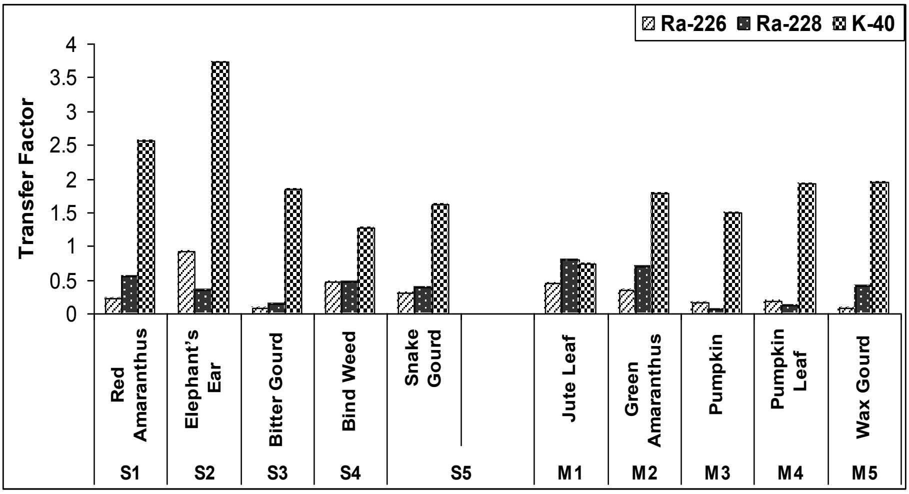

Figure 4: Transfer Factor (TF) of the radionuclides in different plants of Savar and Manikgonj, Dhaka

TF value of ^{40}K in different plants of Savar was about 7 times higher than those of other radionuclides while in Manikganj it was 2 to 10 times higher *(Figure 4)*. The high TF of ^{40}K was probably due to its high mobility in soil and its subsequent uptake by plants. High TF values ranging from 5 to 8 for ^{40}K have also been reported by Ababneh *et al*. (2009).

Relationship between Activity, Transfer Factors (TF) and Soil Parameters

It was possible to get an overview of the influence of the soil parameters on the activity concentrations in soil and plant and the TFs by correlating the activity concentrations and TF with soil parameters.

Among the soil properties studied, sand content, K content and Ca content in the soils of Savar were found to have significant positive correlation with the activity concentration of ^{40}K in soil. This indicates that the availability of ^{40}K in soil increased with an increase in sand, K and Ca content. A significant negative correlation was observed between activity concentration of ^{228}Ra in the soil of Savar and soil CEC which might be due to the fact that higher soil CEC reduces the availability of ^{228}Ra (Table 4).

No significant correlation was found between soil properties and activity concentrations of ^{226}Ra, ^{228}Ra and ^{40}K in soils of Manikganj. However, the activity concentration of ^{40}K in plants showed a significant but negative correlation with soil Ca and Mg content and TF of ^{40}K with that of soil Mg content. This means ^{40}K uptake decreased with increasing soil Ca and Mg content. It can be said from the investigations that the availability and uptake of certain natural radionuclides particularly ^{40}K is inextricably related to the presence of Ca and Mg concentrations in soil (Table 5).

TABLE 4
Correlation of activity concentration of natural radionuclides in soils, plants and transfer factors (TF) with soil properties in Savar

Soil Properties	Activity of ^{226}Ra (Bq/kg)		TF of ^{226}Ra in plant	Activity of ^{228}Ra (Bq/kg)		TF of ^{228}Ra in plant	Activity of ^{40}K (Bq/kg)		TF of ^{40}K in plant
	Soil	Plant		Soil	Plant		Soil	Plant	
Sand (%)	0.157	-0.383	-0.189	-0.527	0.357	0.528	**0.923***	0.394	0.195
Silt (%)	-0.059	0.493	0.271	0.365	-0.061	-0.206	-0.84	-0.361	-0.178
Clay (%)	-0.300	0.0234	-0.035	0.570	-0.709	-0.842	-0.655	-0.273	-0.136
pH	-0.631	0.241	-0.043	0.200	0.243	0.179	0.392	0.195	0.130
CEC (meq/100g)	-0.337	0.212	0.691	**-0.882***	-0.458	-0.209	0.335	0.839	0.851
Organic Matter (%)	0.618	-0.790	-0.353	-0.124	-0.569	-0.468	-0.006	-0.125	-0.162
K (meq/100g)	-0.211	0.022	0.227	-0.769	0.331	0.546	**0.963****	0.733	0.573
Ca (meq/100g)	-0.845	0.7485	0.6037	-0.447	0.331	0.476	0.549	0.719	0.684
Mg (meq/100g)	-0.429	0.205	0.293	-0.679	0.400	0.578	**0.952***	0.761	0.613

*Correlation is significant at 0.05 level
**Correlation significant at 0.01 level

TABLE 5

Correlation of activity concentration of natural radionuclides in soils, plants and transfer factors (TF) with soil properties in Manikganj

Soil Properties	Activity of ^{226}Ra (Bq/kg)		TF of ^{226}Ra in plant	Activity of ^{228}Ra (Bq/kg)		TF of ^{228}Ra in plant	Activity of ^{40}K (Bq/kg)		TF of ^{40}K in plant
	Soil	Plant		Soil	Plant		Soil	Plant	
Sand %)	0.268	0.629	0.080	0.212	0.788	0.800	0.068	-0.804	-0.670
Silt (%)	-0.515	-0.398	-0.296	0.083	0.301	0.312	-0.496	0.467	0.542
Clay (%)	-0.005	-0.357	-0.335	-0.212	-0.793	-0.808	0.158	0.476	0.330
pH	-0.652	-0.620	-0.467	0.010	-0.075	0.075	-0.427	0.853	0.827
CEC(meq/100g)	0.326	0.376	0.261	0.082	0.553	0.573	-0.093	-0.715	-0.538
Organic Matter (%)	0.050	0.699	0.615	0.060	0.057	0.045	0.603	-0.683	-0.756
K (meq/100g)	0.229	-0.318	-0.370	-0.284	-0.856	-0.865	0.153	0.240	0.147
Ca (meq/100g)	0.564	0.623	0.470	0.065	0.427	0.438	0.205	**-0.946***	-0.824
Mg (meq/100g)	0.537	0.869	0.470	0.144	0.388	0.382	0.549	**-0.921***	**-0.929***

*Correlation is significant at 0.05 level

CONCLUSION

Since the level of activity concentrations of natural radionuclides in the soils under investigation were within the range of the world average, it might not pose any radiation hazard to the population. But continuous intake of radionuclides through the food-chain may have some serious health effects on individuals in the long term. It is important to understand the behaviour of radionuclides with respect to mitigation and changes in speciation within the soil, availability for plant uptake with time, different agricultural practices and the significance of recycling through animal manure. As a higher concentration of radioactive substances in the environment is undesirable, investigations should be undertaken to detect the concentration of radionuclides in soil and their transfer to plants in order to take necessary radiological and dosimetric measures with the aim of minimizing the harmful effects of ionizing radiation. It is hoped that the data presented here will help establish a baseline for radioactivity concentrations and TFs of various plants in the Sarvar and Manikganj areas of Dhaka, Bangladesh.

REFERENCES

Ababneh, A. M., S. Maisoun, M. S. Masa'deh, Z. Q. Abaneh, M. A. Mufeed and A. M. Alyassin. 2009. Radioactivity concentration in soil and vegetable from the Northern Jordan Rift Valley and the corresponding dose estimates. *Radiation Protection Dosimetry.* 134(1): 30-37.

Brady, N.C. and R.P. Weil. 2002. *The Nature and Properties of Soils* (13edn.). Upper Saddle River, New Jersey, USA: Prentice Hall.

Bunzl, K. and M. Trautmannsheimer. 1999. Transfer of ^{238}U, ^{226}Ra, and ^{210}Po from slag-contaminated soils to vegetables under field conditions. *Science of the Total Environment.* 231: 91–99.

Chibowski, S. 2000. Studies of Radioactive Contaminations and Heavy Metal Contents in Vegetables and Fruit from Lublin, Poland. *Polish Journal of Environmental Studies.* 9(4): 249–253.

International Atomic Energy Agency (IAEA). 1982. Generic Models and Parameters for Assessing the Environmental Transfer of Radionuclides from Routine Releases. Exposure of Critical Groups. Safety Series, No. 57. IAEA .

International Atomic Energy Agency (IAEA). 1990. *The Environmental Behavior of Radium*. Technical Report Series No. 310. IAEA, Vienna, Austria.

Kabir, K. A., S. M. A. Islam and M. M. Rahman. 2009. Distribution of radionuclides on surface soil and bottom sediment in the district of Jessore, Bangladesh and evaluation of radiation hazard. *Journal of Bangladesh Academy of Sciences*. 33(1): 117-130.

Noordijk, H., K. E. Van, J. Lembrechts and M. J. Frissel. 1992. Impact of ageing and weather conditions on soil-to-plant transfer of radiocesium and radiostrontium. *The Journal of Environmental Radioactivity.* 15: 277–286.

Owono, A. P. 2010. Multi-group approximation, scattering and calibration coefficients, uncertainty estimates and detection limits of a NaI(Tl)-based gamma spectrometry setup for low-level activity analysis. *The Journal of Environmental Radioactivity*. 101: 692–699.

Staven, L. H., K. Rhoads, B. A. Napier and D. L. Strenge. 2003. *A Compendium of Transfer Factors for Agricultural and Animal Products*. Richland, USA. Pacific Northwest National Laboratory.

Sheppard, S. C. and W. G. Evenden. 1988. The assumption of linearity in soil and plant concentration ratio: an experimental evaluation. *The Journal of Environmental Radioactivity*. 7: 221–247.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). 2000. Sources and Effects of Ionizing Radiation. New York, USA . UNSCEAR.

Yassine, T., M. Al-Odat and I. Othman. 2003. Transfer of ^{137}Cs and ^{90}Sr from typical Syrian soils to crops. *Journal of Food Engineering.* XVI: 73–79.