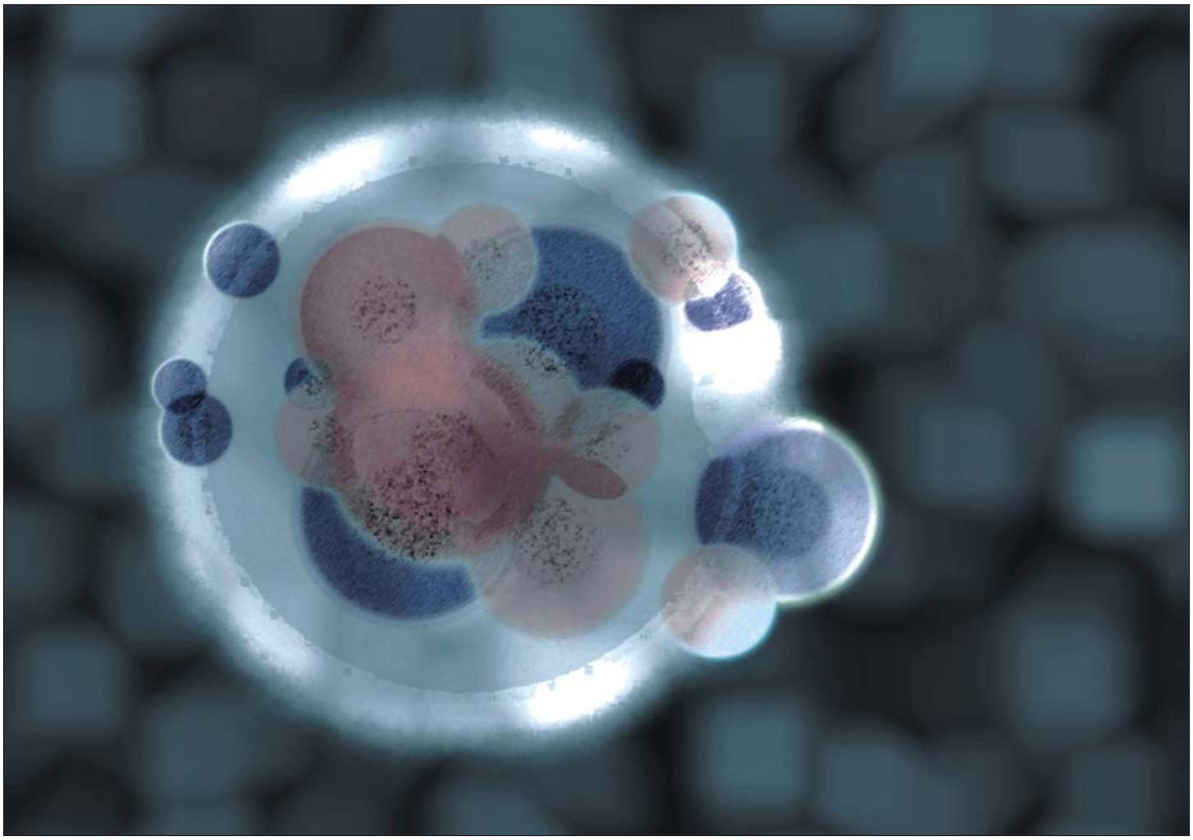

Journal of Biological Sciences

ISSN 1727-3048

Journal of Biological Sciences 7 (4): 673-676, 2007
ISSN 1727-3048

Transfer of Radiocesium from Soil-to-Plant by Field Experiment

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Abstract: In this research, soil-to-plant Transfer Factor (TF) for radiocesium has been measured by field experiment. Soil and grassy plant grown in a contaminated land containing radiocesium in the Atomic Energy Research Establishment (AERE) campus, Savar, Dhaka were collected to investigate the transfer of radiocesium in the soil-plant system. The activities of radiocesium in soil and grassy plant were measured using High Purity Germanium (HPGe) detector coupled with associated accessories. Using the measured activities, TF values were found within the range of 2.7×10^{-2} to 4.7×10^{-2}, which are reasonably comparable with the values found in the literature. Soil characteristics were also investigated to assist the measured TF values for the corresponding soil. This data set might be useful while calculating radiological human dose via the ingestion pathway in the tropical environment.

Key words: Transfer factor, radiocesium, high purity germanium detector, soil characteristics

INTRODUCTION

After accidental release of radionuclides in the environment, they are deposited on ground and consequently accumulated in the plant through uptake process. Among deposited radionuclides, radiocesium (^{137}Cs) is a dominant fission product, which has high relative mobility in the soil-plant system, long-term bioavailability, high radiotoxicity and is long-lived (Rosen and Eriksson, 1998). The plant uptake of deposited ^{137}Cs from soil, commonly expressed as soil-to-plant Transfer Factor (TF) is widely used while calculating radiological human dose via the ingestion pathway. Soil to plant transfer factor; an important parameter needs to be measured adequately to predict a reliable dose to the population through ingestion pathway (IAEA, 2001). There are many studies regarding the TF values for ^{137}Cs performed both for tropical and temperate environments (Skarlou, 1996; IAEA, 1994; Nisbet and Woodman, 2000; Othaman and Yassine, 1995; Bunzl and Kracke, 1987; Jalil *et al.*, 2002). However, a few data performed by pot experiment (Jalil *et al.*, 2002) is available in Bangladesh especially in the vicinity of AERE campus where major nuclear facilities (3 MW TRIGA Mark-II research reactor, a radioactive waste disposal facility likely to be established and a central radioactive waste processing and storage facility) in the country have been established. In the Atomic Energy Research Establishment (AERE) campus, there is a contaminated land containing ^{137}Cs. In the present work, TF value of ^{137}Cs for grassy plants grown in the contaminated land has been investigated. Generally TFs of ^{137}Cs vary often by more than four orders of magnitude depending upon soil type, pH, solid/liquid distribution coefficient, exchangeable K^+, organic matter content, plant species and other environmental conditions (Absalom *et al.*, 2001). The low solid-liquid distribution coefficient (K_D) due to the low clay content and high NH_4^+ concentration in the soil solution enhance TF value of ^{137}Cs. Moreover, the usual low K^+ level in the solid phase and in the soil solution and high organic matter content also enhance root uptake. In the present work, soil characteristics have also been investigated to assist the measured TF values for the corresponding soil. The results obtained in the present work might be useful while

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calculating radiological human dose via the ingestion pathway in the tropical environment valid for many Asian countries.

MATERIALS AND METHODS

Location of the study area: The geographical coordinates of the AERE campus are 23.55°N latitude and 90.11°E longitude. It stands on a topographic high land, which is surrounded by an alluvial flood plain whose average elevation is about 10.70 m above mean sea level. AERE campus and its adjoining areas have a tropical humid climate with high summer temperature, excessive air humidity, heavy rainfall and cool dry winter. The mean annual temperature is about 25°C and the average annual rainfall is about 2.1 m. The southwest monsoon continuing from March to October causes rainfall in the area. Heavy precipitation occurs during the period June-July.

Soil characteristics: A wide range of physical and chemical properties of soil such as pH, exchangeable K^+, organic matter content and clay content is generally responsible for enhancing TF values of ^{137}Cs to plant, both directly and indirectly. Since the uptake of ^{137}Cs to plant is based on soil characteristics, a data set of soil type based on Marshal textural classification was investigated. Apart from this, some available data such as exchangeable K^+, organic matter content and clay content for the same soil described elsewhere (Rabbani *et al*., 1996; Frissel, 2001) were shown in Table 1. The data set described in Table 1 is the average value of the corresponding soil property.

Transfer factor (TF): The term soil-to-plant TF measures the transfer of radionuclides from soil to plant when uptake by plant root is the only process affecting the transfer. From the observed activity concentrations of the radionuclide in the plant and in the corresponding soil, the TF values were calculated according to the following equation.

$$TF = \frac{\text{Activity in plant (Bq/kg fresh weight)}}{\text{Activity in soil (Bq/kg fresh weight)}} \quad (1)$$

The TF is expressed in this experiment in fresh mass basis because fresh mass is required in the radiological assessment. Grassy plant grown at contaminated land containing ^{137}Cs in the AERE campus were selected to measure TF values under field condition.

Field condition: In 1988, an experiment 'Uptake of ^{137}Cs by Commonly Consumed Fresh Water Fishes' was carried out within the AERE campus (Annual Report, BAEC, 1989). Upon completion of the experiment, liquid radioactive wastes originating from this experiment was stored in 200 l drums in an isolated interim storage room within the campus. In 2000, an area (~20×30 m^2) adjacent to the storage room was found contaminated with ^{137}Cs liquid wastes, confirmed by an investigation. The contaminated area is mostly covered by grassy plant (mainly grass) especially during summer and rainy seasons. In the present research work, an investigation on the transfer of ^{137}Cs from contaminated soil to grassy plant grown in this area was carried out under field condition. Different locations were selected for the collection of soil (at a depth of 0-20 cm) and grassy plant samples. Roots were separated from the grassy part of the plants. Collected soils and grassy plants from each location were transported to the laboratory for processing before measurements. These samples were air-dried and grounded with pestle and motor. Special precaution was taken to avoid cross contamination. In the representative plant and soil samples, ^{137}Cs activity was measured directly with the HPGe detector in Marinelli beaker geometry (height • 16.5 cm and diameter = 14.5 cm). The mean ^{137}Cs concentration in soil was observed to be about 30±7 Bq kg$^{\bullet 1}$ with a maximum of 64 Bq kg$^{\bullet 1}$. A typical spectrum of ^{137}Cs having centroid position at 662 k*eV* for both soil and plant is shown in Fig. 1.

Table 1: Soil characteristics in the AERE campus

Components	Measured values
pH	5.80
Exchangeable K^+ ($cmol_c$/kg)	0.51
Organic matter (%)	0.78
Cation Exchange Capacity (CEC) ($cmol_c$/kg)	13.20
Clay (%)	46.50
Silt (%)	43.30
Sand (%)	11.20
Porosity (%)	39-43
Bulk density (g/cm^3)	1.53

Distribution coefficient (K_D): Measurement of the distribution coefficient (K_D) can be performed by the Batch Method with any radionuclide on any soil material or rock. In most cases, the soil material or rock is continually agitated to facilitate mixing and contact. At specified times, to approach equilibrium conditions, the solid and solution are separated. The K_D can be determined as the ratio of concentration of a radionuclide absorbed to solid phase to the concentration of that radionuclide left in liquid phase. The distribution coefficient represents the partition of the solute in the soil matrix and soil water, assuming that equilibrium conditions exist between the soil and solution phases. The K_D used to express the exchange of radionuclides

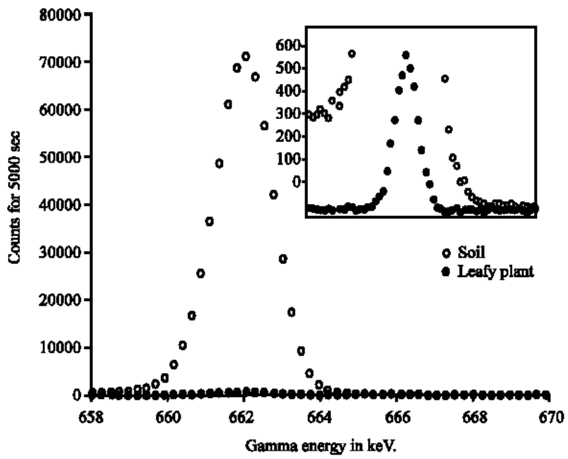

Fig. 1: Gamma Spectra of ^{137}Cs for Soil and grassy plants

between the dissolved and sediment sorbed phases for a given radionuclide for steady state conditions at equilibrium can be expressed as,

$$K_D = \frac{\text{Concentration of radionuclide in solid phase (Bq g}^{-1}\text{)}}{\text{Concentration of radionuclide in liquid phase (Bq mL}^{-1}\text{)}} \quad (2)$$

The K_D for the collected soils was investigated using Batch Method after attaining equilibrium between solid and liquid phase.

RESULTS AND DISCUSSION

The granular compositions of the soil are shown in Table 1. The soil is composed of 11.20% sand, 43.30% silt and 46.50% clay, which lie in silty clay soil based on Marshal textural classification. The chemical properties are also shown in Table 1. The gamma spectra of ^{137}Cs for soil and grassy plants are shown in Fig. 1. It can be seen in this Figure that the peak at 662 keV corresponds to ^{137}Cs. The soil concentration is firmly higher than the concentration in plant. The inset as in Fig. 1 gives the concentration of grassy plant on an expanded scale.

It can be seen in this Fig. 2 that the TF values were $3.10\times10^{\bullet 2}$, $3.20\times10^{\bullet 2}$, $3.50\times10^{\bullet 2}$, $2.50\times10^{\bullet 2}$, $2.90\times10^{\bullet 2}$, $4.20\times10^{\bullet 2}$, $3.5\times10^{\bullet 2}$, $2.8\times10^{\bullet 2}$ and 3.70×10^{2} for points 1, 2, 3, 4, 5, 6, 7, 8 and 9, respectively within the contaminated area. The average TF value was found to be 0.0324±0.004. The measured values are found to be comparable with the values described elsewhere (Jalil *et al*., 2002; Shang and Leung, 2002). The highest TF value was found to be $4.2\times10^{\bullet 2}$ at point 6 while the lowest TF value was found

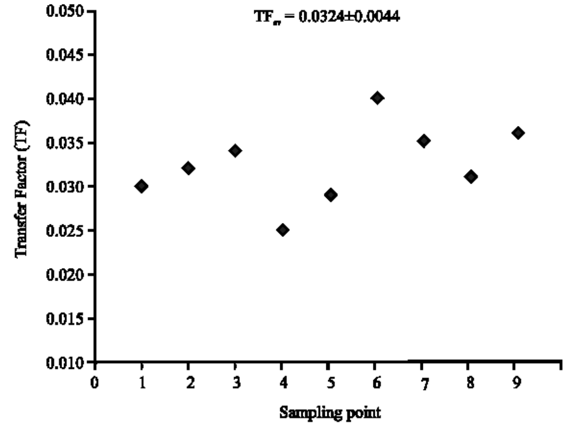

Fig. 2: TF values for ^{137}Cs for the grassy plants

Table 2: Transfer factors of ^{137}Cs published by other Organization (Jalil *et al*., 2002; Shang and Leung, 2002)

Organization	Part of plants	TF value
IAEA	Edible parts of crops	$3.0\times10^{\bullet 2}$
NCRP	Edible parts of crops	$1.5\times10^{\bullet 5}$-0.29
NRPB	Edible plants	$3.8\times10^{\bullet 2}$-$2.9\times10^{\bullet 1}$
US DOE	Vegetable, fruit, grain	$1.1\times10^{\bullet 2}$
US NRC	Edible parts of crops	$1.0\times10^{\bullet 2}$
CEC	Grain	$6.0\times10^{\bullet 3}$
Taiwan RMC	Seed	0.03-0.188
Taiwan RWMC	Rice	$4.0\times10^{\bullet 2}$-$6.0\times10^{\bullet 1}$
Bangladesh	Vegetable, rice	$1.8\times10^{\bullet 2}$-$2.02\times10^{\bullet 1}$

to be $2.5\times10^{\bullet 2}$ at point 4. The variations lie within the ranges compared to the values described in Table 2 which indicate a less considerable variation among different points in the contaminated area. This attributes to a slight variation while calculating radiological dose to the population considering ingestion pathway if uses this measured value. The TF values for the plants could be applied in order to predict more reliable dose assessment via the ingestion pathway.

According to the kinetic study for K_D, the equilibrium condition between soil and liquid phase was attained after 3 h. At equilibrium, the K_D was found to be 320 ml/gm. The K_D value might be useful for dose calculation considering the ground water pathway.

CONCLUSIONS

Soil to plant TF values for the grassy plant grown in the contaminated land of AERE campus have been investigated. Based on Marshal textural classification, it is found that the selected soil is silty clay. The TF values of the grassy plants at different positions were found to be reasonably comparable with the value found in the literature. It has been observed that the variation of measured TF values is acceptable at different positions.

This may attribute to a very small variation of dose considering a single TF value of a plant while calculating radiological dose to the population via ingestion pathway. The measured soil characteristics might provide a data set to assist the measured TF values. This data set might be useful while calculating radiological human dose via the ingestion pathway in the tropical environment.

ACKNOWLEDGMENTS

The authors are thankful to technical staffs of Radiation Monitoring and Waste Management Laboratory, Institute of Nuclear Science and Technology, Atomic Energy Research Establishment, Savar, Dhaka, Bangladesh for their cooperation during experiments.

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