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Determination of Soil-Plant Transfer Factor of Edible Plants Grown in a Contaminated Soil with Europium – 152

[1]Mohammed Elywa, [2]Fawzia Mubarak, [2]H.A. Omar,
[1]A. Nassif, Mansour, [1]Eman Selem and [1]Noura Marwaan

[1]Faculty of Science, Zagazic University, El-Sharkia, Egypt
[2]Rad. Prot. Dept., NRC, EAEA, Cairo, Egypt

Abstract: Aims of this study are determination of activity concentration, Estimation of transfer factors for radionuclides from soil to plant and analyze correlations between soil characteristics and radionuclides concentration. Edible plants cultivated in a soil manually contaminated with specific concentrations of Europium -152 (Eu-152). HPGe detector was used to measure the activity concentration of Eu-152 and naturally occurring radionuclides of four different Egyptian plants; Phaseolus vulgaris (white beans and red beans), Cucumis Sativus (Cucumber) and Cucurbita pepo (Zucchini). The transfer factors for all plants due to absorption of Eu-152 were calculated. Results show that transfer factors values were found to be, the highest value was registered for white bean (0.0267) followed by Red bean (0.018). The lowest activities are those measured for cucumber (0.009) and Zucchini soil (0.008). Comparisons were carried out for these results with that due to absorption of naturally occurring radionuclides by the same plants. The results of transfer factors for both Eu-152 and NORM were in good agreement. Thus, it can be concluded that, white bean has the highest activity, where, Zucchini plant has minimal activity concentration. This indicates that Zucchini plant is weak absorber of Europium -152 radioisotope and thus it is edible plant in any contaminated areas with Eu-152.

Key words: Eu-152 · Transfer factor · Activity concentration · Contaminated soil and NORM

INTRODUCTION

Radionuclides exist in the environment either naturally or artificially, one of them is Europium-152 (Eu-152). This isotope created using neutron activation of the stable isotope (Eu-151) which is a very good neutron absorber and thus is often used in nuclear reactor control rods. The soil-plant-man is the principal pathway being studied for the transfer of radionuclides to human beings [1]. Soils contaminated with radionuclides poses a long-term radiation hazard to human health through exposure via the food chain and other pathways. In previous studies specific radioactivity of residual Eu-152 and other isotopes were measured in roof tile samples exposed to the Nagasaki atomic bomb [2-4]. Normal, artificial and accidental releases of nuclear wastes result in radionuclides that sip into the environment.

The transfer factor is a tool in the form of a mathematical equation that is used to express the uptake of radionuclides from soil by the plants. TF is widely used for calculating radiological human dose via the ingestion pathway [5]. However, wild plants are more contaminated than vegetables produced on farms; the vegetables are the main foods of the people around the world, the activity concentrations of naturally occurring and anthropogenic radionuclides deposited in the agriculture soil and especial crops such as rice [6].

Thus, soil-to-plant TF is regarded as one of the most important parameters in environmental safety assessment for nuclear facilities [7]. TF is essential for environmental transfer models, which are useful in the prediction of radionuclide concentration in agricultural crops for estimating dose impact to human [5].

Several studies have been done on the edible plants growing in the area around the Fukushima Daiichi nuclear power plant which remains contaminated. It was important to identify plants with low levels of contamination for the restoration of agriculture soil in different areas [8-10].

Corresponding Author: Mohammed Elywa, Faculty of Science, Zagazic University, El-Sharkia, Egypt

In the previous studies especially after the Chernobyl disaster (April, 1986) [11-14], it will be essential to cultivate agricultural plants that accumulate low levels of contamination. Such plants can be recognized by studying the soil plant transfer coefficients of many radioisotopes such as Eu-152 and Cs-137.

In this work, naturally occurring radionuclides (U-238, Th-232, K-40) and artificial isotope (Eu-152) activity concentration of four different Egyptian plants; Phaseolus vulgaris (white beans and red beans), Cucumis sativus (Cucumber) and Cucurbita pepo (Zucchini) were measured using HPGe detector with Genie2000 software. Blank soil samples were manually contaminated it with Eu-152 (T1/2=13.7 years).

Aims of this study are determination of activity concentration, estimation of transfer factors of radionuclides from soil to plant, comparison between absorption of NORM and artificial isotope by plants and analyze correlations between soil characteristics and radionuclides concentration.

MATERIALS AND METHODS

Four crops growing in Egypt; white bean, red bean, Cucumber and Zucchini were selected depending upon the daily uses. A normal agriculture soil contaminated with Eu-152 solution to obtain a contaminated soil model for planting.

Soil Bulk Density: The bulk density is the mass of unit volume of an air-dried sample, which includes all solid particles and all voids. It is expressed as:

$$\rho = M / V \text{ (gm/cm}^3\text{)} \quad (1)$$

where;
ρ = bulk density (gm/cm^3),
M= mass of air-dried sample (gm),
V= volume (cm^3) of predetermined mass (M), it was measured using a graduated cylinder.

Sample Preparation: The Eu-152 radionuclide was used as the radiocontaminants. This radionuclide emits a wide range of gamma energies ranging from about 122 KeV to about 1408 KeV, from which convenient pairs of low and high gamma-ray [15].

Soil samples were collected at 5 cm depth from the ground surface, which was the approximate depth of the plant roots. Contaminated soil was prepared at laboratory by homogenously adding 350 mille liter of Eu-152 solution with specific concentrations per kilogram. Four crops were planted in contaminated soils. The seeds of the four plant samples dried and leave in 50 ml of Eu-152 solution with the same concentration for germination process for two weeks. An enough number of dried seeds planted in separated containers within about 1.5 kg of soil for 7 weeks. By the same way, blank plants were grown in uncontaminated (blank) soil. After that, plants were removed carefully, completely dried at 60 °C for 24 hours, mixed thoroughly, weighted and filled in a polyethylene jar with a screw cover and perfectly sealed. Contaminated soil was prepared as plants, then, from 300g to 400 g of soil samples was mixed thoroughly and filled in similar polyethylene jar.

For background measurements, blank soil samples and blank plants were completely dried at a temperature of around 60 ^{0}C. Samples' weight was registered both before and after drying, in order to estimation of water content. From 300g to 400 g of soil samples was mixed thoroughly and filled in a polyethylene jar.

Contaminated soil, plants and blank (background) soil and plants were analyzed using a high purity germanium (HPGe) detector. Each soil sample needed a 6 hours analysis cycle for proper nuclides detection, while plants samples run 24 hours cycles. This difference in analysis duration was due to difference in the activity concentrations. The activities registered were expressed in Bq/kg dry weight.

Activity Estimation (Gamma-Ray Spectrometry): A P-type coaxial HPGe detector, Canberra model no. CPVD 30-3020, with a relative efficiency of 30% and a resolution full width at half maximum (FWHM) of 1.9 keV at 1.33 MeV (with associated electronics) was employed for the measurement of Eu-152 activity.

The main characteristics required for such detection system is high efficiency, high-energy resolution and very low background. Especially the background features of the system are of considerable importance, as they must be known in order to get an estimate of the detection limits and the minimum detectable activity [16-17].

The efficiency calibration consists in determining a function describing the ã-rays energy Eã versus the full energy peak (FEP) detection efficiency. It is usually a polynomial with the degree higher than 2. Radioactive standard sources with gamma-ray emissions covering a wide energy range using Eu-152 radionuclide for this purpose. The ^{152}Eu radionuclide was chosen because the calibration energies obtainable from it will cover the entire range of energies over which measurements are to be made. The source was placed at a distance reasonably close to the detector and suitable for the geometry conditions used in the experiment. The spectrum was measured for 3600 seconds and the peaks which correspond to the following energies were used: 1408, 1112, 964, 779, 344 and 122 keV.

For a given peak corresponding to the energy Eã in the gamma-ray spectrum measured with a HPGe detector, for each measurement a calibration coefficient for a specific radionuclide was calculated as follows [18-20].

$$\varepsilon = \frac{(A - A_F).A_D}{t.I.\Delta.F_C F_T} \quad (2)$$

where ε is the efficiency and its expanded standard uncertainty,

A and A_F are the net areas of the considered peak from the gamma-ray spectrum of the standard, respectively. t is the measurement time expressed in seconds; F_C, F_T and F_D are the multiplicative coefficients for coincidence summing corrections, efficiency transfer corrections and for the decay during the reference time and the time of the sample measurement start; I is the emission probability of the considered gamma-rays; A_2 is the activity of the standard, expressed in Bequerel units (Bq).

To determine the activity and the soil-plant transfer coefficients (TF) of Eu-152, using the following equations;

$$A = \frac{CPS \times 100 \times 1000}{eff. \times I \times W} \quad (3)$$

Where A is the activity in Becquerel (Bq) of a radionuclide, eff. is the detector % efficiency, I is the gamma line intensity and W is the weight in gram.

Data Treatment: The transfer factor (concentration ratios) is a tool in the form of a mathematical equation that is used to express the uptake of radionuclides from soil by the plants. It is defined as the ratio of the activity concentration in fungal fruit bodies or green plants (Bq kg^{-1} fresh weight or Bq kg^{-1} dry weight) divided by the activity concentration of the specific soil layer exploited by the mycelium or the root system (Bq kg^{-1} dry weight) [1, 21-23]. For Eu-152 it is obtained by the activity of plant dry matter divided by the activity of dry soil matter.

$$TF = \frac{Activity\ of\ radionuclides\ in\ plant\ (Bq\ kg^{-1}\ dry\ weight)}{Activity\ of\ radionuclides\ in\ soil\ (Bq\ kg^{-1}\ dry\ weight)} \quad (4)$$

Where, TF is the transfer coefficient of the Eu-152.

The observed variability of the experimentally determined transfer coefficient of the different food and forage plants complicates the use of a generalized concentration factor value to be employed in the prediction of transfer factor of radionuclides in different food and forage plants. As these factors vary significantly with changes in climate each country has to generate its own data base [24].

RESULTS AND DISCUSSIONS

Figure (1) shows the interesting part of a typical gamma rays spectrum measured on HPGd instrument. Figure 1 (A) shows the Eu-152 energy peaks of a soil sample contaminated with Eu-152 and Figure 1(B) shows the energy peaks of Zucchini plant grown on it. The counting live-time was 1110 secs. The important identified photopeaks and their associated radionuclides are depicted.

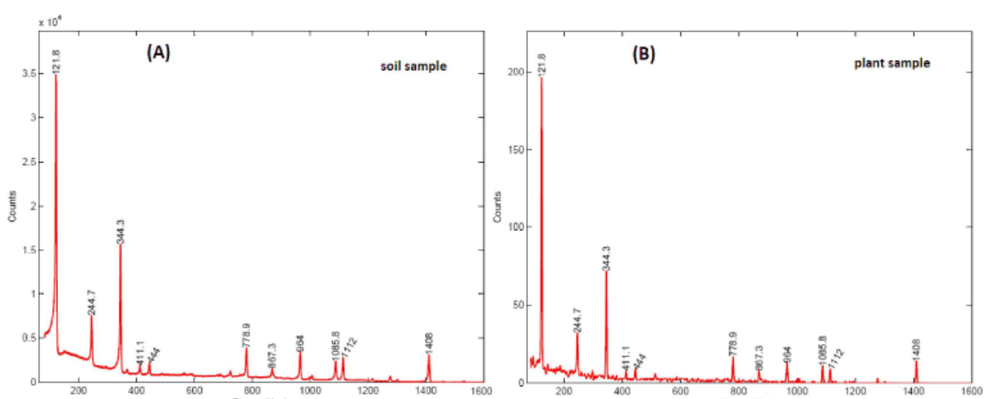

Fig. 1: Gamma spectra of soil and plant samples acquired by HPGd gamma detector. (A) Shows the photopeaks of Eu-152 of a contaminated soil. (B) Shows the gamma spectrum of a Zucchini plant.

Table 1: Activity concentration and the transfer factors of Eu-152.

Samples	Soil Activity (Bq)	Plant activity (Bq)	Transfer factor	
White bean	191.05 ±44.39	5.10 ± 0.8	0.026695	2.67%
Red bean	210.03 ± 58.3	3.72 ±0.85	0.017712	1.77%
Cucumber	407.53 ±75.91	3.50 ± 1.37	0.008588	0.86%
Zucchini	1084.04 ± 243.89	8.77 ± 1.62	0.00809	0.81%

Table 2: Activity concentration for plants and soil due to NORM.

Activity Concentration (Bq) - NORM							
soil	U-238	Th-232	K-40	Plant	U-238	Th-232	K-40
W.B	16.67	14.876	71.25	W.B	*1.64*	*0.979*	3.67
R.B	16.04	18.38	89.77	R.B	*1.42*	*1.19*	3.58
CU	27.66	17.16	92.92	CU	*1.72*	*0.63*	4.02
Zu	18.05	17.32	94.76	Zu	*0.64*	*0.47*	3.56

Table 3: Transfer factors due to NORM.

Transfer Factor -NORM			
soil	U-238	Th-232	K-40
W.B	0.098	0.066	0.052
R.B	0.089	0.065	0.040
CU	0.062	0.037	0.043
Zu	0.035	0.027	0.038

Table (1) shows the activity concentration for each plant and its specific soil which contaminated with Eu-152 isotope. The averaged activity concentrations of the four different plants and soils were displayed. The highest value for soil was registered for zucchini soil (1084.04 Bq) followed by cucumber soil (407.53 Bq). The lowest activities are those measured for red bean soil (210.03 Bq) and white bean soil (191.05 Bq).

The vice versa was recorded for transfer factors, the highest value was registered for white bean (0.0267) followed by Red bean (0.018). The lowest activities are those measured for cucumber (0.009) and Zucchini soil (0.008).

Comparisons were carried out for these results with that due to absorption of naturally occurring radionuclides by the same plants. The results of transfer factors for both Eu-152 and NORM were in good agreement as shown in table (2) and (3).

Figure 1 shows a graphical presentation of the transfer factor for Eu-152. White bean shows the highest value in low and high concentrations. Red bean shows slightly higher values compared to cucumber and zucchini appear to be very low.

This slight difference can probably be attributed to the nature of the soil composition, mobility of radionuclides in clays soils is enhanced. Also, the nuclide's characteristics affect the mobility of radionuclises from soil to plant [25]. These results were compared with absorption coefficients for the same plants due to naturally occurring radionuclides as shown in figure (2). It can be concluded that the transfer coefficients due to NORM represented the same behavior as that of Eu-152, i.e., White bean shows the highest value in low and high concentrations. Red bean shows slightly higher values compared to cucumber and zucchini appear to be very low.

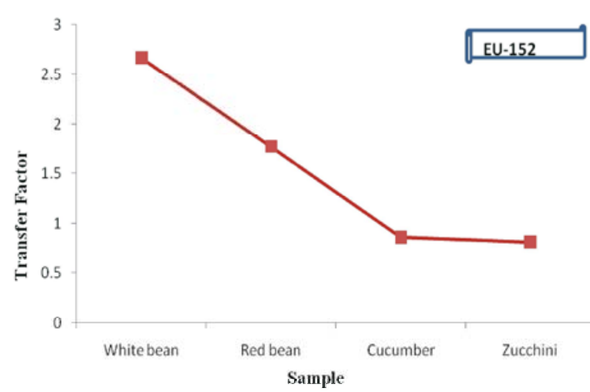

Fig. 1: Transfer coefficients for different plants contaminated by Eu-152.

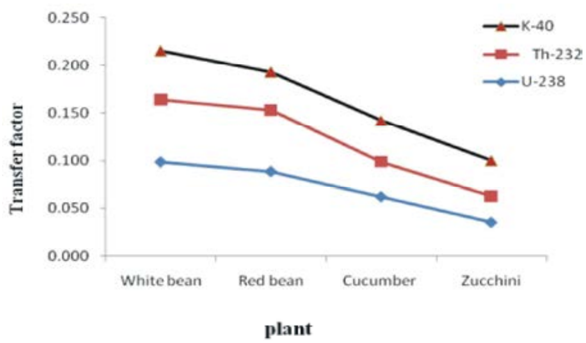

Fig. 1: Transfer coefficients for different plants due to natural radioactivity.

CONCLUSION

It is clear the difference between transfer factors in four plants due to natural or artificial radionuclides. White bean shows the highest value in low and high concentrations. Red bean shows slightly higher values compared to cucumber and zucchini appear to be very low. Comparisons were carried out for these results with that due to absorption of naturally occurring radionuclides by the same plants. The results of transfer factors for both Eu-152 and NORM were in good agreement. Thus, it can be concluded that, white bean has the highest activity, where, Zucchini plant has minimal activity concentration. This indicates that Zucchini plant is weak absorber of Europium -152 radioisotope and thus it is edible plant in any contaminated areas with Eu-152

This slight difference can probably be attributed to the nature of the soil composition and radionuclide's characteristics.

REFERENCES

1. Nicola Pallavicini, 2011. Activity concentration and transfer factors of natural and artificial radionuclides in the Swedish counties of Uppsala and Jämtland", Master's Thesis, Swedish University of Agricultural Sciences, Department of Soil and Environment.
2. Nakanishi, T., K. Miwa and R. Ohki, 1998. Specific Radioactivity of Europium-152 in Roof Tiles Exposed to Atomic Bomb Radiation in Nagasaki. JRR Journal of Radiation Research, 39(4): 243-250.
3. Kato, K., M. Habara, T. Aoyama, H. Sakata and Y. Yoshizawa, 1990. Gamma-Ray Measurement of 152 Eu Produced by Neutrons from the Hiroshima Atomic Bomb and Evaluation of Neutron Fluence. Jpn. J. Appl. Phys. Japanese Journal of Applied Physics, 29: 1546-1549.
4. Shizuma, K., K. Iwatani, H. Hashi, T. Oka, H. Morishima and M. Hoshi, 1992. Specific Activities of 60Co and 152Eu in Samples Collected from the Atomic-Bomb Dome in Hiroshima. JRR Journal of Radiation Research, 33: 151-162.
5. Ehlken, S. and G. Kirchner, 2002. Environmental processes affecting plant root uptake of radioactive trace elements and variability of transfer factor data: A review. Journal of Environmental Radioactivity, 58(2-3): 97-112.
6. Chakraborty, S., R. Azim, A. Rezaur Rahman and R. Sarker, 2013. Radioactivity Concentrations in Soil and Transfer Factors of Radionuclides from Soil to Grass and Plants in the Chittagong City of Bangladesh. Journal of Physical Science, 24(1): 95-113.
7. Sheppard, S., 2011. Review of "Handbook of Parameter Values for the Prediction of Radionuclide Transfer in Terrestrial and Freshwater Environments. Journal of Environmental Radioactivity, 102(2): 217.
8. Koibuchi, Y., 2013. Tracing fine-grained sediment transport around Tokyo Bay using cesium-134 and cesium-137 originating from Fukushima Daiichi Power Plant. *Coastal Processes III*.
9. Ishii, K., S. Itoh, D. Sata, S. Matsuyama, A. Terakawa, S. Kim and T. Kamiya, 2014. Micro-PIXE analysis of the distribution of cesium in clay particles for environmental remediation of Fukushima. International Journal of PIXE Int. J. PIXE, 24(03n04): 131-136.
10. Ishii, K., A. Fujita, S. Toyama, A. Terakawa, S. Matsuyama, H. Arai and K. Kasahara, 2015. The Determination of Soil-plant Transfer Coefficients of Cesium-137 and Other Elements by ã-Ray Measurement and PIXE Analysis, for use in the Remediation of Fukushima. Physics Procedia, 66: 278-286.
11. Zhu, Y., 2000. Plant uptake of radiocaesium: A review of mechanisms, regulation and application. Journal of Experimental Botany, 51(351): 1635-1645.
12. Thiry, Y., C. Colle, V. Yoschenko, S. Levchuk, M.V. Hees and P. Hurtevent, 2009. Journal of Environmental Radioactivity, 100: 1062-1068.
13. Bunzl, K. and W. Kracke, 1989. Health Physics, 57(4): 593-600.

14. Isaure M.P., A. Fraysse, G. Devès, P. Le Lay, B. Fayard, J. Susini, J. Bourguigno and R. Ortega, 2006. Biochimie, 88: 1583-1590.
15. Adejumo, O.O. and F.A. Balogun, 2012. Using the Dual Energy Gamma-Ray Transmission Technique to Measure Soil Bulk Density and Water Content of Central Southwestern Nigerian Soils‘, Journal of Environmental Protection, 3: 1409-1427.
16. Mackenzie, A., 2000. Environmental radioactivity: Experience from the 20th century — trends and issues for the 21st century. Science of The Total Environment, 249(1-3): 313-329.
17. Knoll, G.F., 2003. Nuclear Radiation Detection Devices. Encyclopedia of Physical Science and Technology, pp: 763-773.
18. Adesanmi, C.A., F.A. Balogun, M.K. Fasasi, I.A. Tubosun and A.A. Oladipo, 2001. J. Rad. Nucl. Chem., 249(3): 607-611.
19. Abbas, M.I., 2006., Appl Radiat Isot, 64: 1661-1664.
20. Arnold, D. and O. Sima, 2004. Appl Radiat Isot, 61: 117-121.
21. International Atomic Energy Agency, 2002. “Modelling the Migration and Accumulation of Radionuclides in Forest Ecosystems”, IAEA-BIOMASS-1, ISBN 92–0–114902–6.
22. International Atomic Energy Agency 2010. “Handbook of parameter values for prediction of radionuclide transfer in terrestrial and freshwater environments”, Technical Reports Series no. 472.
23. Sheppard, S.C., M.I. Sheppard, M. Ilin and P. Thompson, 2005. Soil-to-plant transfers of uranium series radionuclides in natural and contaminated settings”, Radioprotection, Suppl. 1(40):: 253-S259.
24. Sadhasivam Meena and Tamil Nadu 2006. Soil -Plant Transfer of Radiocaesium (Cs-137) and Dependance on Soil Properties, 18th World Congress of Soil Science July 9- 15 Philadelphia, Pennsylvania, USA
25. Blanco Rodríguez, P., F. Vera Tome´, J.C. Lozano and M.A. Pérez-Fernández, 2008. Influence of soil texture on the distribution and availability of 238U,230Th and 226Ra in soils, Journal of Environmental Radioactivity, 99: 1247-1254.