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Transfer factors of Polonium from soil to parsley and mint

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ABSTRACT

Transfer factors of ^{210}Po from soil to parsley and mint have been determined. Artificial polonium isotope (^{208}Po) was used as a tracer to determine transfer factor of Po from soil to plant in pot experiments. Two plant growing systems were used for this study namely, an outdoor system and a sheltered system by a polyethylene tent. ^{208}Po and ^{210}Po were determined in soil and different parts of the studied plants (stem and leaf), using alpha spectroscopy. The results have shown that there was a clear uptake of ^{208}Po by roots to leaves and stems of both plants. Higher values of transfer factors using the ^{210}Po activity concentrations than the ^{208}Po activity concentration were observed. Transfer factors of ^{210}Po from soil to parsley varied between 20×10^{-2} and 50×10^{-2} and 22×10^{-3} and 67×10^{-3} in mint, while ^{208}Po transfer factors varied between 4×10^{-2} and 12×10^{-2} for parsley and 10×10^{-2} and 22×10^{-2} in mint. Transfer factors of Po were higher in those plants grown in the sheltered system than in the open system; about 75% of Po was transferred from atmosphere to parsley parts using the two systems. Ratios of transferred Po from soil to mint stem and leaf in the sheltered system were higher by 2 times from those in the open system.

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1. Introduction

Polonium-210 (half life = 138.4 days) is directly produced during the radioactive decay of its parent radionuclide, ^{210}Pb; which is, in turn, a member of ^{238}U decay series. ^{210}Po is found at elevated concentrations in association with ^{226}Ra sources, but it is often detected at some distance from sites of release due to the extreme mobility of the noble radon gas, ^{222}Rn (half life = 3.8 days). The rapid decay of ^{222}Rn in the atmosphere generates ^{210}Po and ^{210}Pb, which are rapidly adsorbed by aerosols and returned to earth surface (Ivanovich and Harmon, 1992; Eisenbud, 1987). In addition ^{210}Po is found in the presence of uranium-bearing ores such as in phosphate and uranium mines and it also occurs in other minerals such as shale, coal and industrial products and wastes such as phosphate and the oil and gas industry (Al-Masri and Al-Bich, 2002; Berger et al., 1965; Bunzl and Trautmannsheimer, 1999; Chen et al., 2005; Francis et al., 1968; Hill, 1960; Pietrzak–Flis and Skowrofiska, 1995).

Many studies have been carried out to determine TFs (the ratio of radionuclide concentration in plant to radionuclide concentration in soil per unit mass) for most important artificial radionuclides (^{90}Sr and ^{137}Cs) in agricultural products (IAEA, 2009). The TF is usually used for evaluating the impact of releases of radionuclides into the environment. On the other hand, natural environmental radioactivity arises mainly from primordial radionuclides, such as ^{40}K, and the radionuclides from the ^{232}Th and ^{238}U series, and their decay products are considered to be the main contributor to internal radiation dose. Several studies on transfer of natural radionuclides including ^{210}Po from soil to plant have been carried out in different regions in the world (Martinez-Aguirre et al., 1997; Simon and Ibrahim, 1987; Tracy et al., 1983; Paul and Pillai, 1986; Pulhani et al., 2005; Bunzl and Trautmannsheimer, 1999; Martinez-Aguirre, and Perianez, 1998; Staven et al., 2003; Ewers et al., 2003; Blanco Rodriguez et al., 2006; Tome et al., 2003; Al-Masri et al., 2008). However, only soils to plant transfer factors are considered in these studies.

Polonium enters the human food chain via plant uptake from soil and/or water, and particle deposition onto plant surfaces. Careful studies, which discriminate between each source, are rare and most of them consider the polonium activity concentration in plant parts for determination of soil to plant transfer factors; only root uptake system is usually considered (Al-Masri et al., 2008; Blanco Rodriguez et al., 2006; Ewers et al., 2003; Martinez-Aguirre and Perianez, 1998; Pietrzak–Flis and Skowrofiska, 1995; Pulhani et al., 2005; Sheppard and Evenden, 1992; Tome et al., 2003; Tracy et al., 1983; Watson, 1983). However, the main source

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of ^{210}Po in plant is the deposition of both ^{210}Pb and ^{210}Po on plant surfaces during rainfall events or dry deposition (Francis et al., 1968; Pietrzak–Flis and Skowrofiska, 1995). One study (Pietrzak–Flis and Skowrofiska, 1995) was carried out to discriminate between the two components of polonium transfer to plant, namely, soil to plant and air to plant by dry and wet deposition. Two types of plant growing systems were used; an open field and sheltered field. According to their results, wet deposition was found to be the main source of ^{210}Pb and ^{210}Po in the above ground parts of the studied plants. However, the results are highly affected by the ambient air conditions, and the deposition of ^{210}Po in Syria with rain is much lower than in the experiment of Pietrzak-Flis and Skowrofiska. Therefore, a method is proposed to discriminate between the ^{210}Po transfers from air to upper parts of the plants and from soil to plant via root uptake. The method is based on the use of ^{208}Po, an artificial Po isotope, to determine Po transfer from soil to different parts of two vegetables widely consumed in Syria; namely mint and parsley.

2. Materials and methods

2.1. Soil collection and soil analysis

Two agricultural soil samples (50 kg each) were collected from farms near Damascus city. The collected soil samples were air-dried. Particles larger than 1.7 mm were removed by sieving. All further tests were performed on the less than 1.7 mm size fraction of the soils. Soil pH was determined in soil H_2O solution 1:5. The electrical conductivity and particle size distribution were determined by a method described by Black et al. (1984). The organic matters, cation exchange capacity (CEC) were analyzed according to Page et al. (1982).

2.2. Soil preparation and homogeneity test

30 kg of each soil sample was divided into 6 sub-samples. Each sub-sample was spiked with ^{208}Po (about 350 Bq) (Polonium chloride in 0.1 M HCl provided by Amersham International UK), using distilled water (500 ml for each pot) and mixing. The sub-sample was dried and homogenized using the automatic homogenizer for 24 h. Homogeneity test was performed for each sub-sample by analyzing 4 aliquots for parsley and 6 aliquots for mint for ^{208}Po. The results were statistically analyzed using ANOVA program. The samples were then placed in 12 pots ready for planting.

2.3. Parsley and mint planting

Six pots were planted with 3 g of parsley seeds each and the other 6 pots were planted with 6 mint roots each. Two pots of each group were placed into a polyethylene tent, and the remaining pots were left under the field conditions. Irrigation was done twice a week. The plants were harvested and the parsley and mint samples were discrete to stems and leaves. Each part was washed with distilled water, dried at 85 °C and grounded.

2.4. Determination of ^{210}Po and ^{208}Po

The ^{210}Po and ^{208}Po (half life = 2.898 y) were measured using the standard technique (the silver disc technique) (Flynn, 1968). Two grams dry wt. of soil or 10 g of plant samples were taken in duplicate samples. One of each duplicated samples were spiked with 0.2 Bq of ^{208}Po (Polonium chloride in 0.1 M HCl provided by Amersham International UK) as a yield tracer. Each sample was digested using concentrated nitric acid for at least 24 h; hydrogen peroxide was also added to help in oxidizing the organic compounds. When the solution was clear, the sample was then gently evaporated to near dryness. The residue was then dissolved in 100 ml of 0.5 M hydrochloric acid. The solution was then heated to 80 °C and ^{210}Po and ^{208}Po were spontaneously plated onto a rotating silver disc after reduction of iron with ascorbic acid. Alpha counting of ^{208}Po (5.15 MeV) and ^{210}Po (5.3 MeV) was done using an alpha spectrometer (Oasis, Oxford) with a passive ion-implanted silicon detector (active area 300 mm^2, background counts per day 3.6 and the minimum depletion thickness 100 μm). The ^{210}Po activity was corrected for recovery by comparison with measured activity of the ^{208}Po yield tracer and for radioactive decay since the time of sampling. The ^{208}Po activity was determined using internal standard technique. The lower limit of detection (MDA) of the method used was 0.4 Bq kg^{-1}. Where MDA was determined by analyzing 10 replicates of real plant sample with a known activity of ^{210}Pb (about 5–7 times of MDA). The standard deviation (STD) of these ten replicates was calculated. Then MDA was calculated from the following equation:

$$\mathrm{MDA} = 3\ \mathrm{STD}$$

2.5. Quality control procedures

Quality control procedures were applied using home-made control samples, reference samples provided by IAEA (IAEA-326 and IAEA-327) and duplicate analysis. In addition, all methods and laboratories used in this study are validated according to Eurachem Guide.

2.6. Transfer factor calculation

Transfer factor from soil to plant was calculated from the following equation:

$$\mathrm{TF} = \frac{C_{\mathrm{iP}}}{C_{\mathrm{iS}}} \tag{1}$$

where: C_{iP} is ^{208}Po activity in dried plant (Bq kg^{-1}) and C_{iS} is ^{208}Po activity in dried soil (Bq kg^{-1}).

3. Result and discussion

3.1. ^{208}Po and ^{210}Po activities in soil and plant samples

Table 1 shows the mean values of the fresh weight and drying weight factor for all pots. The results show that the parsley in open field grows up better than those in sheltered field. Inversely, the mint in open field grows up worst than those in sheltered field.

Table 2 shows some of the physical and chemical characteristics for the two soil types used in the present study. Electrical conductivity (ECE) (the standard measure of salinity) was found to be 952 and 521 μS cm^{-1} for the mint and parsley soils, respectively. pH ranges between 7.54 and 7.64, while the organic content is about 5.09% and 4.57% for mint and parsley soil, respectively.

Initially, ^{208}Po was well mixed to ensure good homogeneity of the soil used in the experiments. ANOVA single factor statistical program was used to analyse the variance in ^{208}Po activities determined in aliquots and the variances between the sub-samples. On the other hand, ^{210}Po homogeneity was not taken in consider because the ^{210}Po activity will change with time due to ^{210}Pb and ^{210}Po fallout and variation of ^{222}Rn activity, so ^{210}Po relative uncertainties will be much big.

Uncertainties of measurements (U_{CV}) in aliquots and between sub-samples for ^{208}Po determination are calculated by the following equation:

Table 1
Fresh weight and drying weight factor for all pots.

Plant part	Open field		Sheltered field	
	Fresh weight (g)	Drying factor	Fresh weight (g)	Drying factor
Parsley leaf	20 ± 5	0.16 ± 0.00	11 ± 3	0.17 ± 0.01
Parsley stem	24 ± 8	0.13 ± 0.01	10 ± 3	0.15 ± 0.01
Mint leaf	62 ± 4	0.21 ± 0.02	95 ± 13	0.17 ± 0.01
Mint stem	34 ± 2	0.26 ± 0.02	57 ± 4	0.23 ± 0.01

The results = Mean of fresh weight (for the pots, 4 samples for open field and 2 samples for sheltered field) ± 1STD.

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