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Research Article

Activity concentration and transfer of ^{210}Po and dose due to consumption of the velvet bean, *Mucuna pruriens* (L.) DC. var. *utilis* (Wright) Burck.

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Abstract

The activity concentration of naturally occurring radionuclide ^{210}Po were determined in *Mucuna pruriens* (L.) DC. var. *utilis* (Wright) Burck. collected from three different locations of Kanyakumari District. ^{210}Po activity concentration in velvet bean were estimated in poded, depoded and soil samples. Activity concentration of ^{210}Po in plant and soil were measured by employing alpha radiation counting system. Maximum activity concentration of ^{210}Po (0.84±0.08 Bq/kg) recorded in bean+ pod samples collected from Puthalam, whereas lowest activity concentration (0.09±0.01 Bq/kg) recorded in bean samples collected from Pallam. Transfer factor (TF) values were maximum in Puthalam site (1.23). Total annual commited effective dose to the public was found to be 2.81 to 4.68×10^{-7} µSv/yr from depoded bean sample and 12.17 to 17.47×10^{-7} µSv/yr from poded bean sample.

INTRODUCTION

Polonium is a chemical element with the symbol Po with the half-life of 138.4 days and present in the atmosphere as decay product of ^{222}Rn (half-life 3.8 days). Both ^{210}Pb and ^{210}Po attach to aerosol particles in the atmosphere and deposit onto the ground as dry and wet deposition, which is their main source in surface soil (Avadhani et al., 2005). The ^{210}Po in soils may originate either as a product of the radioactive decay of radionuclides of ^{238}U series present in the soil or the result of the precipitation of radon decay products from the atmosphere (Kirchner and Daillant, 1998), Soil in turn is a major source of these radionuclides entering the food chains (Gerzebek et al., 2005) Thus studies on behavior and distribution of radionuclides in soil are of great significance. Polonium enters the human food chain through plant uptake from soil (Watson, 1983).

Legumes are considered as the major source of protein, however, the protein and their aminoacid constituents are less when compared to animals. Studies may reveal more on the relationship between moisture and proteins in seeds in relation to ^{210}Po concentration. ^{210}Po has been reported to have affinity for protein in edible soft tissues and will be biomagnified through food chain in northern hemisphere (Lichem-caribou-wolf), wherein it behaves as a sulphur or selenium analogue (Thomas et al., 1994). Being rich in proteins, carbohydrates, calorific value, fibre and vitamins, legumes constitute the staple food in many countries (Deshpande, 1992; Devi *et al.*, 2012; Mogle , 2013; Parveen *et al.*, 2012) . Exploitation of underexplored wild legumes is an important approach to combat the protein-energy malnutrition in developing countries. The nutritional quality and overall acceptability of legumes has been impaired, largely by the occurrence of anti-nutritional factors (e.g. lectins, phenolics, phytic acid and trypsin inhibitors) (Thompson and Erdman, 1982; Liener, 1994).

Among wild legumes, the genus *Mucuna* (velvet beans) belonging to family Leguminosae is widespread in tropical and sub-tropical regions of the world and is considered an alternative protein source, Besides their high nutritional value (Bressani, 2002) seeds of *Mucuna* have great demand in local markets, mainly for the presence of L-DOPA (3,4-dihydroxy-L-phenylalanine), a potential neurotransmitter used in the treatment of Parkinson's disease (Prakash and Tewari, 1999; Nagashayana et al., 2000). The greatest impediment to promotion of *Mucuna* as food or feed is the presence of antinutrients, which are high in contrast to other unconventional legumes (e.g. *Canavalia*, *Sesbania*). The documentation of the level of natural radionuclides in the environment and man is especially important wherever elevated radiation background exists. The objective of the present study was to measure the concentration of primordial nuclide (^{210}Po) in soil and in the poded and depoded velvet beans and to calculate the transfer of ^{210}Po from soil to plant (beans with and without pods). Radiation dose due to consumption of the velvet beans to humans was also assessed.

MATERIALS AND METHODS

Collection and preparation of samples

Velvet bean samples (*M. pruriens*) were collected from three sites (Pallam, Puthalam and Karumpattoor). Collection site were located along the southwest coast of Kanyakumari district. Homegardens in these sites were visited during the period, August 2013 to July 2014, and mature pods ready for plucking were collected and brought to the laboratory for further studies. Beans which were ready for consumption were collected along with the pods. The fresh weight of the bean along with the pods were noted. Then, the samples were divided into two: (i) the pods along with the beans were dried and the sample processed (ii) the beans after drying, were de-poded and processed separately. The soil sample in the root zone of the *M. pruriens* were collected. Leaf and debris were removed before sampling. The soil sample was collected upto a depth of 30cm the zone upto which the roots extended. All the samples were then homogenized using stainless steel blender, sieved and packed.

Analysis of ^{210}Po

About 10 g of the dried samples (both beans and soil) were homogenized and transferred to a 250 ml conical flask and digested with the concentrated HNO_3 : concentrated HCl (3 : 1), followed by concentrated HNO_3 : H_2O_2 (1 : 1) mixture. This procedure was repeated until a clear precipitate was obtained. The final clear white residue was dissolved in 100 ml of 0.5 N HCl. This process of wet digestion was adopted because ^{210}Po is highly volatile at temperatures above 80°C.

The sample solution in 0.5 N HCl was placed on a magnetic stirrer with thermostat control at a temperature of 90°C. Ascorbic acid (100 mg) was added to reduce ferric ions to ferrous ions, thus eliminating interference in the electrochemical deposition of polonium. A brightly polished silver disc (0.8 mm thickness and 2.5 cm diameter) of predetermined background was suspended in the sample solution by means of a nylon thread. The silver disc was kept spinning for a period of 4 hours with the aid of the stirrer. Spontaneous deposition of ^{210}Po on both sides of the silver disc took place under these conditions. At the end of the plating, the disc was taken out, rinsed with distilled water, dried and counted for activity on both sides in an alpha counter.

Measurement of ^{210}Po concentration

After the spontaneous deposition of ^{210}Po on the silver planchette alpha activity was measured on the both sides of silver planchette using radiation counting system (Nucleonix RC 605 A) with an alpha counter of ZnS (Ag) solid scintillation detector, having a background of 0.005 counts per second (cps) and counting efficiency of 30 – 32%. The calculation was done in the Microsoft Excel software package with the following formulae:

$$\text{Net cps} = \frac{(S_1 - B_1) + (S_2 - B_2)}{C}$$

where, S1= Sample counts of side 1, S2= Sample counts of side 2, B1= Background counts of side 1, B2= Background counts of side 2, C= Counting time (sec).

$$\textbf{Activity concentration} = \frac{\text{Net CPS x 100 x 1000}}{\text{E x Q}}$$

where,
CPS = Counts per second, E = Efficiency of the counting system, Q = Quantity of sample taken for analysis

$$\textbf{Standard deviation} = \frac{\text{SD x 100} \times \text{D x 1000}}{\text{E x Q}}$$

where,
SD = Standard deviation of the Net CPS, D = Dry weight of the sample,
E= Efficiency of the counting system, Q = Quantity of sample taken for analysis

$$\text{Corrected activity} = \text{Activity} \times e^{\ln 2}\left(\frac{\text{difference in days}}{138.378}\right)$$

Transfer Factor

$$\textbf{Transfer factor} = \frac{\text{Activity in beans (Bq kg}^{-1}\text{ d.w)}}{\text{Activity in Soil (Bq kg}^{-1}\text{d.w)}}$$

Dose Estimation

The dose conversion factor (IAEA, 1996) for ^{210}Po is: 1.2 µSv/Bq
Using the activity intake data and IAEA dose conversion factors, the dose to the individual members of the population was calculated using the formula given below.

$$D_{ing} = C_R \times I_F \times E_D$$

Where, D_{ing} is the annual effective dose to an individual due to ingestion of radionuclides (µSv/yr), C_R is the concentration of radionuclides in ingested food (Bq/kg), I_F is the annual intake of food containing radionuclides (kg/yr) and E_D is the ingestion dose conversion factor for radionuclides (µSv/Bq).

RESULTS AND DISCUSSION

The ^{210}Po activity concentration in the velvet bean samples were found to be in the range of 0.09±0.01 Bq/kg fresh weight (f.w.) and 0.45±0.05 Bq/kg dry weight (d.w.) in the samples collected from Pallam; 0.1±0.01 Bq/kg fresh weight (f.w.) and 0.31±0.03 Bq/kg dry weight (d.w.) in the sample collected from Puthalam whereas the sample collected from Karumbatoor showed activity concentration of about 0.15±0.02 and 0.55±0.08 fresh and dry weight respectively. In the velvet bean+pod samples collected from the three sites, the highest ^{210}Po activity concentration 0.56±0.05 fresh weight and 0.84±0.08 dry weight was recorded in the sample collected from Puthalam whereas the site Karumbatoor showed the least activity concentration showing 0.39±0.04 and 0.52±0.05 fresh and dry weight respectively. The activity concentration of about 0.47±0.08 Bq/kg fresh weight (f.w.) and 0.71±0.12 Bq/kg dry weight (d.w.) was noticed in the Pallam study site. Studies of the perennial mat-forming wild legumes, *Canavalia cathartica* and *C. maritima* by (Bhat et al., 2005) revealed the differential bioaccumulation of ^{210}Po by different parts. They also found that the beans exhibited the lowest values in terms of activity. Although ^{210}Po has affinity for proteins, it did not concentrate too much in seed proteins of *Canavalia* sp. (Ross et al., 2013) who extensively studied the activity concentrations of ^{210}Po in various vegetables, found its concentration to be higher in the 'pulses' group when compared to the other vegetable category.

Table 1: Mean activity concentration of ^{210}Po in soil samples

Place of sampling	Activity concentration of ^{210}Po in soil (Bq/kg d.w.)
Pallam	1.02±0.07
Puthalam	0.69±0.09
Karumbatoor	1.14±0.07

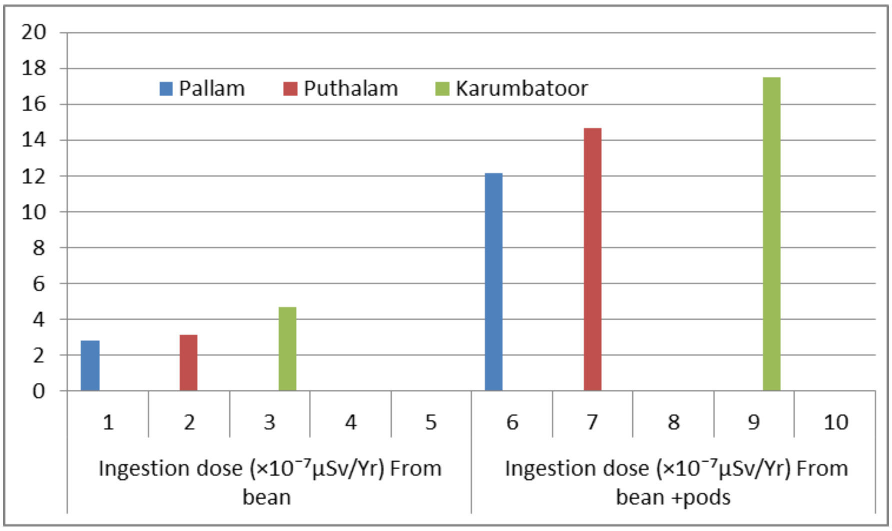
Table 2: Mean activity concentration of ^{210}Po in bean and bean +pod samples

Place of collection	Activity concentration (Bq/kg) in bean		Activity concentration (Bq/kg) in bean +pod	
	Fresh weight	Dry weight	Fresh weight	Dry weight
Pallam	0.09±0.01	0.45±0.05	0.47±0.08	0.71±0.12
Puthalam	0.1±0.01	0.31±0.03	0.56±0.05	0.84±0.08
Karumbatoor	0.15±0.02	0.55±0.08	0.39±0.04	0.52±0.05

Table 3: Transfer Factor of ^{210}Po from soil to bean and bean+pod samples

Study site	Transfer factor	
	From soil to beans	From soil to beans+pods
Pallam	0.44	0.7
Puthalam	0.45	1.23
Karumbatoor	0.48	0.46

Fig.1 Ingestion dose due to consumption of beans and beans+pods



Mean activity concentration of ^{210} Po in soil

The soil samples collected from the study sites, the lowest ^{210}Po activity concentration (0.69 ± 0.09 Bq/kg d.w.) was noted in the sample collected from Puthalam and the highest (1.14± 0.07 Bq/kg d.w.) in the sample collected from Karumbatoor. The sample collected from Pallam registered the moderate activity (1.02±0.07 Bq/kg d.w.) (Vaaramaa et al., 2010) revealed that the mean total inventory in the soil profile, up to 20 cm, of ^{210}Po was 5.5 kBq/m^2 (range 4.0 - 7.4 kBq/m^2), the organic soil layer containing 45% of the total inventory of this radionuclide. Another factor to be noted is that, the region is a high natural background radiation area with the presence of monazite, the ore of ^{232}Th.

Transfer Factor of ^{210} Po from soil to bean and bean+pod sample

The transfer of the radionuclide ^{210}Po from the total soil fraction to the velvet bean sample was found to be 0.44 in the sample collected from Pallam; 0.45 in the sample collected from Puthalam. (Al-Masri et al., 2008) revealed that transfer factors for ^{210}Po varied between 2.8×10^{-2} and 2 in fruits of egg plant and grain of barley respectively, (Ross et al.,2013) found out that fruits, leafy vegetable, pulses, cereals, tubers and roots, and palm embryo registered high transfer factors for ^{226}Ra.

Ingestion dose due to ^{210}Po caused by consumption of Velvet beans

The annual ingestion dose due to consumption of an average of 50g of beans (with and without pods) per week was calculated .The dose range varied from 2.80 to 4.68×10^{-7} µSv/yr in the bean samples. The beans+pods collected from Karumbatoor delivered the lowest ingestion dose 12.17×10^{-7} µSv/yr and the highest dose 17.47×10^{-7} µSv/yr was processed by the sample collected from Puthalam. The sample collected from Pallam showed ingestion dose of about 14.66×10^{-7} µSv/yr. This implies that the ingestion dose due to ^{210}Po caused by the consumption of beans+pods is one order of magnitude higher than that caused by the consumption of beans alone. The annual intake of ^{210}Po by the population residing in this location through dietary sources was estimated by (Rani et al., 2014) reported that total annual committed effective dose to the public due to ^{210}Po was found to be 2.24 mSv/yr in an area located in a high natural background radiation area of Kanyakumari coast.

The beans (poded) had a comparatively lesser activity concentration of ^{210}Po when compared to the beans+pods (depoded) sample. This implies a differential distribution of this radionuclide in the beans and the pods. In the soil samples collected from the three study sites, the lowest ^{210}Po activity concentration was noted in the sample collected from Puthalam and the highest in the sample collected from Karumbatoor. Hence the contribution to the radiation dose because of the consumption of velvet beans is very less, with this implication that these beans are safe for human consumption.

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