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An assessment of the ^{210}Po ingestion dose due to the consumption of agricultural, marine, fresh water and forest foodstuffs in Gudalore (India)

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ABSTRACT

The activity concentration of ^{210}Po in cereals, pulses, food materials of animal origin, vegetables and spices collected from Gudalore (India) has been estimated by radiochemical method. The activity concentration of ^{210}Po in cereals is found to vary from 124 to 604 mBq kg^{-1}. Raw rice registered the highest mean activity 504 ± 61 mBq kg^{-1}. In pulses ^{210}Po activity concentration varies from 42 to 320 mBq kg^{-1} and the highest activity is found in black lentil with the average value of 172 ± 38 mBq kg^{-1}. Leafy vegetables registered the highest ^{210}Po activity concentration (662–7336 mBq kg^{-1}) and are followed by tuber vegetables (390–1269 mBq kg^{-1}) and then by other vegetables (75–595 mBq kg^{-1}). The higher concentration of ^{210}Po observed in leafy vegetables may be attributed to the dry deposition of ^{210}Po and other daughter products of ^{222}Rn on large leaf surfaces from the air. Among animal products fish of marine origin registered the highest ^{210}Po activity concentration 36,850–48,964 mBq kg^{-1}. The mean ^{210}Po activity concentration in coffee has been estimated as 7500 mBq kg^{-1}. The activity concentration of ^{210}Po in leaf and bark of tree *Cinnamom zeylanicum*, a popular spice, is found to vary from 3500 to 11,100 mBq kg^{-1} and 1600–3400 mBq kg^{-1}. The consumption of marine and fresh water fish contribute 60.7% (506.1 μSv y^{-1}) to the total ingestion dose received. Cereals being consumed in a large scale, contribute 23.4% (194.9 μSv y^{-1}) of the total ingestion dose received. The contribution from spices and leafy vegetables consumed is 5.8% (48.1 μSv y^{-1}) and 6.5% (54.3 μSv y^{-1}), respectively. The remaining 3.6% (30.0 μSv y^{-1}) contribution to the total ingestion dose comes from other food materials and vegetables.

1. Introduction

Radiation related health hazards have created greater awareness, not only among the scientific community, but also among the general public, due to their deleterious impact on people. Human beings and other living organisms are continuously being exposed knowingly or not to ionizing radiation. Natural radioisotopes, which are the source of ionizing radiation, are present everywhere on earth. The environment where we live contains primordial radionuclides which are found in soils, rocks, vegetables, water and building materials, and this is a significant contributor to the collective dose to human beings (El-Arabi, 2007). About 85% of the total radiation dose received by the general public arises from naturally existing sources of radiation and the remaining is due to anthropogenic radionuclides (UNSCEAR, 2000). This emphasizes the importance of having knowledge about the concentration of naturally existing radionuclides in different matrices of the environment.

Naturally occurring radionuclides contribute to the radiation exposure received by the general public in two distinct ways, namely: external exposure and internal exposure. External radiation exposure is caused by the gamma rays emitted from ^{238}U and ^{232}Th decay series and singly occurring ^{40}K isotopes present in soil, rock and building materials. Internal radiation exposure is due to the inhalation of air containing radioisotopes and the ingestion of food materials containing natural radioisotopes (IAEA, 1989; Jabbar et al., 2010). The internal radiation dose received by the general public can be classified into two forms, namely: inhalation and ingestion. The radiation dose received through the inhalation of airborne radionuclides constitutes the inhalation dose, ^{222}Rn, ^{220}Rn and their short-lived daughters are major contributors to the inhalation dose. The ingestion dose is the radiation dose received through the isotopes consumed with food.

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Many isotopes in the uranium and thorium series found in all types of food materials and water are the main sources of the ingestion dose. In the uranium series ^{210}Po is one of the most important radionuclide which deliver a significantly high dose via ingestion. It is an alpha emitter and has a half-life of 138.4 days. As a pure alpha emitting radionuclide with a high specific activity of ~1.7×10^{14} Bq g^{-1}, ^{210}Po poses a considerable radiation risk even with minimal intake due to its high linear energy transfer (LET). It is suggested that the toxicity of ^{210}Po is comparable to ^{239}Pu and about 5 times greater than that of ^{226}Ra (ICRP, 1995; Harrison et al., 2007; Scott, 2007; Jefferson et al., 2009). It has been estimated that about 7% of the total internal dose received from natural isotopes is due to the ingestion of ^{210}Po (Bulman et al., 1995; Clayton and Bradley, 1995). The ingested radiation dose received varies significantly between individuals and communities, and depends on locality, lifestyle and diet. The main source of ^{210}Po in plants and surface soil is ^{222}Rn gas which is diffused into the atmosphere from rocks and soil where it ultimately decays into ^{210}Pb, ^{210}Bi and then into ^{210}Po. The ^{210}Po attaches itself electrostatically to aerosol particles and is transported back to the surface soil, plant and aquatic environments by dry deposition and wash out (Santos et al., 1990; Pietrzak-Flis and Skowronska-Smolak, 1995; Karali et al., 1996; Persson and Holm, 2011). Radionuclides present in the environment are transferred to plants through (i) uptake from soil through roots and (ii) direct absorption through the aerial parts of plants. The former depends on the radionuclide activity concentrations in the soil, and the latter on the rate of radionuclides deposition from the atmosphere (Linsalata, 1994). ^{210}Po is also generated in plants from radioactive decay of ^{226}Ra absorbed from soil and water (Karali et al., 1996). The burning of fossil fuels such as coal and the enhanced use of phosphate fertilizers in agriculture are the other sources of ^{210}Po in vegetable and other food materials (Pietrzak-Flis and Skowronska-Smolak, 1995).

Many investigators have studied the distribution of ^{210}Po in different marine organisms (Iyengar, 1983; Yamamoto et al., 1994; Bangera and Rudran, 1995; Aarkorg et al., 1997; Saito and Cunha, 1997; Kannan et al., 2001; Raja and Shahul Hameed, 2010). The content of ^{210}Po in terrestrial sources has been studied worldwide by many investigators (Carvalho, 1988; Santos et al., 1990; Amaral et al., 1992; Othman and Yassine, 1995; Kannan et al., 2001; Louw et al., 2009; Tuukka et al., 2011; Persson and Holm, 2011). It has been found that there is a scarcity of data on the distribution of ^{210}Po in dietary materials and vegetables cultivated in India. The knowledge is sparse about the distribution of ^{210}Po in spices which are also used as medicine and other tropical plants of human interest. The diet consumed by the general public contains various food materials such as, cereals, pulses, vegetables, food materials of animal origin at different quantities. In view of this, an attempt has been made to study the distribution of the activity concentration of ^{210}Po in vegetables and spices which grew in Gudalore, the study area as a part of systematic background radiation study. For the estimation of the ingestion dose received due to ^{210}Po by the general public knowledge about the concentration of ^{210}Po in cereals, pulses and food materials of terrestrial and marine animal origin is essential and has also been estimated in the present work. The distribution of ^{210}Po in composite diet samples is required for the estimation of actual ingestion dose received by the general public, and it has been estimated and presented in this study.

2. Materials and methods

2.1. Study area

The Gudalore study area is situated at the starting point of the western slope of the western ghat, which is known for its splendid natural environment and as a major tourist attraction in India. Gudalore is situated in south India with its centre at 11° 30′N, 076° 30′E. The altitude of this region varies from 750 to 1240 m above mean sea level. Fig. 1 shows the study area and sampling locations. Gudalore is also one of the leading regions in vegetable, coffee and spice production. Concentrations of ^{210}Po in vegetables cultivated have been estimated using the radiochemical method. For the estimation of the actual ingestion dose received by the general public due to ^{210}Po the activity concentration of ^{210}Po in food materials like cereals, pulses, food materials of marine and terrestrial animal origin have also been estimated. It has been felt worthwhile to study the distribution of ^{210}Po in some tropical forest plants used as spice and medicine, since a considerable portion of the study area is covered with forest. The number of samples analyzed is given in the square bracket appears in the table.

2.2. Vegetables sampling

Different varieties of vegetables grow widely in the study area, Gudalore. These have been classified as leaf vegetables, root vegetables and other vegetables, and have been collected for ^{210}Po estimation. Leaf vegetables studied include: *Centella asiatica*, greens (*Amaranthus* species) and radish leafs (*Raphanus sativus*). These vegetables were collected during the months of March to May. The tuber vegetables included in this study includes tapioca (*Manihot esculenta*), ginger (*Zingiber officinale*), radish (*R. sativus*) and elephant yam (*Amorphophallus campanulatus*), which were collected during the months of June–April. The radionuclides content in beans (*Phaseolus vulgaris*), bittergourd (*Momordica charantia*), tomato (*Lycopersicum esculentum*), eggplant (*Solanum melongena*), *Solanum torvum*, banana (*Musa paradisiaca*) and papaya (*Carica Papaya*), which comes under other vegetable category has also been estimated, which were collected during the months of March–May. These vegetables have been collected at different places in the study area Gudalore.

2.3. Sampling of cereals, pulses and food materials of animal origin

The food materials such as rice (*Oryza sativa*) boiled and raw, black lentil (*Vigna mungo*), *red lentil* (*Cajanus cajan*) and moong bean (*Vigna radiata*) have not been cultivated in the study area. The ^{210}Po content in these materials has also been estimated, to determine the actual dose received through ingestion. Important food materials of animal origin consumed in the study area include fish of marine and fresh water origin, chicken and mutton. Marine fish (*Scomberomorus guttatus*), chicken and mutton samples were collected from the market, whereas the sample of fresh water fish (*Mugil cephalus*) was collected from the reservoirs in this area. Cereals, pulses, fish of fresh water and marine origin, chicken and mutton samples were collected during the months of September–November.

2.4. Composite diet sampling

The diet consumed by the general public contains various quantities of food materials such as cereals, pulses, vegetables, food materials of animal origin at various proportions. The concentration of ^{210}Po in the composite diet gives us actual ingestion dose received by the general public. The composite diet containing breakfast, lunch and dinner of vegetarian and non-vegetarian types has been collected from the selected houses in the study area and stored in a refrigerator. The vegetarian and non-vegetarian diet samples were collected during the months of September–November.