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Distribution of radiocesium and natural gamma emitters in pine needles in coniferious forest sites of Izmir

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Abstract

Using a high-resolution gamma-spectrometer system, the activity concentrations of ^{7}Be, ^{137}Cs, ^{40}K and ^{226}Ra were determined in the pine needles. Activity concentrations of the concerned radionuclides in the needle samples were as follows: ^{7}Be, 24.6 ± 2.40 to $210\pm7.21\,\mathrm{Bq\,kg^{-1}}$, ^{40}K, 23.5 ± 12.4 to $287\pm15.6\,\mathrm{Bq\,kg^{-1}}$, ^{226}Ra, 0.44 ± 0.12 to $12.3\pm2.18\,\mathrm{Bq\,kg^{-1}}$, and ^{137}Cs, 0.61 ± 0.30 to $2.29\pm0.38\,\mathrm{Bq\,kg^{-1}}$. It is found that the frequency distributions obtained for ^{7}Be and ^{137}Cs can be fitted to a normal distribution, and for ^{40}K and ^{226}Ra can be fitted to a log-normal distribution.

Keywords: Radiocesium; Natural radionuclides; Pine needle; HPGe

1. Introduction

It is known that radionuclides present in the environment transfer to plants through uptake from soil through root, and then they are incorporated metabolically into plants. In addition to root uptake, direct deposition may occur on foliar surfaces, and when this happens the radionuclides may be absorbed metabolically by the plants. The root uptake depends on the total amount of radionuclide in the soil as a reservoir and the direct deposition on the rate of radionuclide deposition from the atmosphere (Karunakara et al., 2003; Papastefanou et al., 1999). Dry and wet particles deposited on a forest canopy are adsorbed temporarily on the front of the canopy and transfer by adsorption to the inner and the lower parts of the tree by the interaction of the chemical species between leaves and rainwater. Rainwater and aerosols including their radionuclides are usually deposited on the top of the forest and transferred from upper and younger leaves to lower and older leaves (Osaki et al., 2003). While some radionuclides are taken up as homologous of essential elements, other radionuclides are taken up irrespective of their biological necessity. Besides the well-known essential elements for the growth and reproduction of vegetation, a number of other natural radioactive elements like uranium, thorium and their progenies, cosmogenic radionuclide such as ^{7}Be and artificial radionuclides such as ^{137}Cs are known to be present in plants in varied concentrations (Karunakara et al., 2003). Plants differ considerably in their uptake of the radionuclides. Some species are known to absorb significant amounts of radionuclides and are often used as biological indicators. Pine has a wide distribution in the northern hemisphere and is frequently used as a good indicator for diagnosing anthropogenic pollution. Pine needles are often sampled to study the deposition and impact of air pollutants (Saito et al., 2003; Viksna et al., 1999, 2001). While such studies have found wide applications in many regions of the world, they have not documented in Aegean ecosystems before.

In the coniferous species, the concentrations of the ^{137}Cs within different parts of trees shows that needles and twigs tend to contain the highest concentrations. After deposition has occurred, pattern in soil radioactivity concentrations may arise due to the radioactivity deposited through

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the plant canopy by washout, leaching, litter fall, etc. (Nimis, 1996). In radionuclide cycling within forest ecosystems, litter fall represents the main pathway of radionuclides returning to forest soil. Radionuclides are also transferred from the needles to soil via rain, giving rise to horizontal radioactivity patterns in soil (Strebl et al., 1999; McGee et al., 2000).

There is a lack of information for Turkish forest ecosystems for the characterisation of field data aimed at determining parameter values to be applied in modelling the behaviour of natural and artificial radionuclides following hypothetical releases from a radioactive waste repository. Therefore, a radioecological study was carried out at the forest sites in and around Izmir that were contaminated by deposition after the Chernobyl accident (Yaprak and Karadeniz, 2005; Karadeniz and Yaprak, 2007). As the studies showed that the mushrooms as well as the pine needles are the important component of the forest ecosystems and as the pine needle can be collected at any season and place in Izmir forests, special focus was put on the pine species in this study. It is well known that atmospheric deposition of ^{7}Be has been investigated in many studies from the aspects of both radiation protection and geochemistry (Caillet et al., 2001; Osaki et al., 2003; Ioannidou et al., 2005), especially it has long been used as an environmental tracer in the study of material transfer from the air (Al-Azmi et al., 2001; Ueno et al., 2003; Sato et al., 2003; Hernandez et al., 2004; Todorovic et al., 1999). In this regard, data on ^{7}Be and other natural and artificial radionuclides in pine needles of the Izmir forest region have not previously been reported and the present study is the first systematic effort to provide data on this aspect.

2. Materials and methods

2.1. Study area and sample description

The study was carried out between September 2002 and June 2003 in 11 coniferous forest sites of the Izmir. The studied areas which characterised by natural forest sites are located in latitudes 38°16′N to 39°17′N and longitudes 26°36′E to 28°04′E, at altitude between 48 and 1225 m above sea level. The climate is temperate. The annual ambient temperature varies from −4.6 to 35.5 °C with an average level of 17 °C, the lower value corresponds to the early morning hours of winter season and the higher value corresponds to early afternoon hours of summer. The mean annual precipitation is 1316 mm, with a maximum in September and October. The prevailing winds are East and Northeast directions. For this study, 11 sampling stations (Gölcük, Bozdağ, Kemalpaşa Çınardibi, Bornova Çiçekli, Bornova Çatalçeşme, Kemalpaşa Kurudere, Soma Naldöken, Soma Uruzlar (North and South Region), Bergama Aşağıbey and Mordoğan) were selected. Sampling locations, altitudes, annual precipitation and the botanical name of pine species are given in columns 2–5 of Table 1. Annual precipitation data were provided by the Meteorological Head-office and taken from the closest station from the sampling site.

The soil in the study area is classified as *Dystric Xerorthent* (US taxonomy) and rich in organic matter. The coniferous forest sites and surrounding communities consists of pines (*Pinus nigra*, *Pinus sylvestris*, *Pinus brutia*). The forest floor was covered with dead pine needles (litter) underlying thick humus composed of organic materials, degraded pine needles.

2.2. Sample collection and processing

Fresh needles well exposed to the atmosphere were collected from trees at randomly selected sites in forest stands. And litter newly fallen were collected on ground (1–5 cm). About 1–2 kg of fresh needle and litter samples were collected in a polythene bag and fresh weights were noted. Air-dried needle samples were dried to a constant weight at 80 °C for 24–48 h in an electric oven. The loss of weight on drying (d.w. loss) was calculated for each sample. Dried samples were ground in a small mill and the ground material (200–300 g) transferred to 1000 ml Marinelli beaker prior to analysis.

2.3. Gamma-spectrometric measurements

A 184 cc p-type coaxial HPGe detector with a relative efficiency of 25% and a resolution of 1.85 keV at 1.33 MeV (with associated electronics produced from EG&G Ortec) was employed for the measurement of ^{137}Cs, ^{7}Be, ^{40}K and ^{226}Ra activity in the needle samples. The detector was enclosed in a 100 mm thick lead shield. The spectrum was acquired and analysed by employing a PC-based multichannel analyser and associated software. The detector efficiency calibration was performed by using the IAEA quality assurance reference materials produced from IAEA. The standard materials and samples were taken in containers of the same size and type so that detection geometry remained the same (Marinelli beaker). Samples were counted long (10,000 s) enough to reduce the counting error. Since ^{7}Be has a half-life of 53.3 days, the samples were counted as early as possible for ^{7}Be activity. The samples were then stored for a minimum of 40 days to allow equilibrium between ^{226}Ra and its daughters and counted again for the ^{226}Ra and ^{40}K activity estimation. The activities of ^{137}Cs, ^{40}K and ^{7}Be were derived from their characteristic gamma lines $E_\gamma = 662$ keV (85%), $E_\gamma = 1461$ keV (11%) and $E_\gamma = 477$ keV (10.3%), respectively. The activity of ^{226}Ra was evaluated from the 1764 keV gamma line of its daughter ^{214}Bi. The minimum detectable activity (MDA) for ^{137}Cs, ^{7}Be, ^{226}Ra and ^{40}K in this spectrometer was 0.01, 0.1, 2 and 4.36 Bq kg^{-1}, respectively (for a counting time of 10,000 s and a sample weight of 1650 g). ^{137}Cs, ^{7}Be, ^{226}Ra and ^{40}K activity concentrations per unit mass in Bq kg^{-1} dry weight (dry wt) were determined in the fresh needle and litter samples.