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Vertical distributions of ^{210}Pb excess, ^{7}Be and ^{137}Cs in selected grass covered soils in Southeast Queensland, Australia

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Abstract

Net accumulated areal activity densities and profiles of $^{210}Pb_{ex}$, ^{7}Be and ^{137}Cs in the surface 10 cm of the soil are reported for eight sites in Southeast Queensland, Australia. Areal activity densities of $^{210}Pb_{ex}$ and ^{7}Be varied from 1080 to 4100 Bq m^{-2} and from 176 to 778 Bq m^{-2}, respectively. A significant ($p < 0.001$) portion of the variance ($R^2 > 0.99$) in their vertical distributions was explained by depth in the profile using an exponential function. Around 85% of accumulated $^{210}Pb_{ex}$ was present in the surface 10 cm of the soil. Beryllium-7 was mainly confined to the grass and surface 2 cm of the soil. Average penetration half-depths of 3.6 ± 0.2 and 0.3 ± 0.1 cm were determined for $^{210}Pb_{ex}$ and ^{7}Be, respectively. Areal activity densities of global fallout ^{137}Cs varied from 10 to 361 Bq m^{-2}. Its signal was well mixed within the surface 10 cm. Comparison of the measured ^{137}Cs values to the estimated input value for the region ($\sim$490 Bq m^{-2}) and profiling of a 1 m deep soil core suggests a vertical migration of ^{137}Cs over the past decades.

The paleo-radon activity flux determined from the $^{210}Pb_{ex}$ areal activity density (5.1 ± 0.9 mBq m^{-2} s^{-1}) was not statistically different to that measured using activated charcoal cups (5.5 ± 0.4 mBq m^{-2} s^{-1}), tending to suggest that Southeast Queensland is neither a net source nor a net sink of ^{210}Pb-bearing aerosols.

Keywords: $^{210}Pb_{ex}$; ^{7}Be; ^{137}Cs; Soil; Areal activity density; Penetration half-depth; Radon activity flux; Australia

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1. Introduction

Dictated in part by the geomorphological and ecological consequences of human development over the past decades, a number of nuclear techniques have been developed for quantitative assessment of soil erosion and sedimentation rates. Among these, ^{137}Cs has been extensively used to estimate rates of soil erosion (Ritchie and Ritchie, 2005). This technique compares the ^{137}Cs areal activity density at an eroded site to a nearby undisturbed site to assess the extent of soil loss. Similar methods based on the measurement of ^{210}Pb excess (^{210}Pb$_{ex}$) over ^{226}Ra and ^{7}Be have more recently been established (Zapata, 2003).

Caesium-137, ^{210}Pb and ^{7}Be are all highly particle reactive (see Matisoff et al., 2002 and references therein). Their deposition to earth labels the land surface with a unique and identifiable radiological fingerprint. Due to differences in their half-life and fallout history, these radionuclides are suitable for estimating erosion rates over different timescales. Fissiogenic ^{137}Cs (half-life, 30.2 years) can provide a retrospective estimate of land erosion rates over the past 30–40 years (Zapata, 2003), i.e. since the cessation of large-scale nuclear weapon tests in the atmosphere, lithogenic ^{210}Pb (half-life, 22.6 years) offers a means of estimating erosion rates dating back 100 years (Walling and He, 1999; Walling et al., 2003), and ^{7}Be (half-life, 53.3 days) can provide an estimate of soil loss associated with a single erosive event (Blake et al., 1999; Wilson et al., 2003).

Southeast Queensland presently has the highest population growth in Australia (Australian Bureau of Statistics, 2005). Coupled to this growth, urban development has been identified as a key factor which may accelerate erosion rates in Queensland (Environmental Protection Agency, 2004). To lessen the risk of erosive degradation in populous urban areas, legislative land management practices have been introduced. In the State's southeast and along much of the coastal stretch rainwater runoff poses the greatest threat of erosion, especially during summer when high intensity rainfall usually occurs (Environmental Protection Agency, 2004). For the purpose of monitoring rates of land erosion in these areas, quantitative and reproducible methods are required. To highlight the possibility of nuclear methods for future estimates of land erosion rates in Southeast Queensland, in particular the potential usefulness of ^{210}Pb$_{ex}$ and ^{7}Be, this paper examines vertical distributions of ^{210}Pb$_{ex}$, ^{7}Be and ^{137}Cs in selected grass covered soils in the region. In addition, as the main source of ^{210}Pb$_{ex}$ in surface soils is likely to stem from ^{222}Rn released to the atmosphere, ^{222}Rn exhalation rates from the ground have also been measured. Comparison of these exhalation rates with the ^{210}Pb$_{ex}$ areal activity density can provide additional information about the behaviour and fate of ^{210}Pb in the environment.

2. Materials and methods

2.1. Soil sampling sites

Soil samples were collected from eight sites along a linear route intersecting the coastline of Southeast Queensland at Southport and extending inland approximately 80 km to Boonah (Fig. 1). Sites selected for soil sampling were flat open areas having a uniform grass cover and set in a semi-natural environment showing no apparent signs of disturbance. The slope of the terrain at each site was measured at several points. Slopes of less than 2° were generally recorded, though at Clagiraba (Site 4) the slope of the land was up to 5° at some points. All sites were outside any land areas used for cattle grazing or other agricultural activities, i.e. the land had not been tilled. Occasionally the grass at these sites was clipped