Background radiation dose-rates in a high mountain habitat in Norway

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INTRODUCTION

In recent years, there have been intensive activities on a global basis in relation to the development of methodologies for assessing impacts of ionising radiation on the environment. At a European level, the EURATOM-funded project ERICA, Environmental Risk from Ionising Contaminants: Assessment and Management, (Larsson, in press) has proven to be a driving force in this respect. A key activity in this project was to consider the transfer of radionuclides through food-chains, irrespective of whether humans constitute a component of the food-chain or not, with special focus on provision of data for reference organisms. These organisms, representing the broader ecosystem, provide a basis for radiation dose rates estimations from a contaminated environment.

Arguably, two points of reference may be used for the purpose of assessing the potential consequences of exposures to radiation on non-human biota. These are (a) natural background dose rates and (b) dose rates known to have specific biological effects on individual organisms (Pentreath, 2002). Bands of derived consideration levels for reference fauna and flora could be compiled by combining information on logarithmic bands of dose rates relative to normal natural background dose rates, simply as a means of presentation, plus information on dose rates that may have an adverse effect on reproductive success, or result in early mortality (or cause morbidity), or are likely to result in scorable DNA damage for such organisms (ICRP, 2003). Such a banding would be interpreted on the basis that additions of dose rate that were only fractions of their background might be considered to be trivial or of low concern; those within the normal background range might need to be considered carefully; and those that were one, two, three or more orders of magnitude greater than background would be of increasingly serious concern because of their known adverse effects on individual fauna and flora (Pentreath, 2002).

Numerous data deficiencies have been uncovered in addressing issues related to the characterisation of background dose rates to reference organisms. However, on further inspection it becomes evident that some of these data deficiencies could be easily mitigated with limited, but focussed, effort involving field-work and analysis. The objective of this work was therefore to identify data gaps in relation to the levels and transfer of naturally occurring radionuclides in terrestrial ecosystems and to plan and conduct a terrestrial field campaign with the purpose of filling some of these information gaps. This would facilitate the calculation of more robust background dose-rates for selected terrestrial system hitherto not studied.

IDENTIFICATION OF KNOWLEDGE GAPS

The empirical data coverage (Concentration ratios, CRs, and thereby activity concentrations in plants and animals) for selected radionuclides provided by the ERICA project for terrestrial

environments is presented by Beresford et al. (in press). The coverage for Pb is reasonable presumably reflecting the large number of stable element studies that have been conducted on this element. Other radioelements are more poorly characterised with empirical data sets. In the case of Polonioum, some information is available for flora but only for the fauna group mammals. In the latter case it should be noted that although 36 data are available these represent "all mammals" from a single geographical area - the UK. The number of values associated with Thorium is low. In all cases the number of available empirical values is below 20 and for 7 reference categories no information is available at all. A similar situation exists for Uranium although arguably floral reference organisms are endowed with reasonable CR information. For radium there are severe data deficiencies for invertebrates, insects, amphibia and reptiles.

The Environment Agency of England and Wales recently commissioned work to develop databases to underpin environmental impact assessment (Beresford et al., 2007) using reference animals and plants. In considering an overview of these data, there are no data for some Reference animals and plants, notably frog, bee, earthworm and rat and very few data for some other groups, notably duck (^{40}K only) and deer (^{40}K, 1 data point for ^{210}Po). In order to address this numerous samples were measured predominately for U and Th. New data were generated for, *inter alia*, ducks, trout and insects thus providing some new information to fill data gaps albeit specifically for the UK environment. However, no new measurements of ^{210}Po were made in the study.

FIELD CAMPAIGN

A field study was planned and implemented at Dovre, Central part of Norway (62°17' N, 9°36' E) during the period 17-20th June 2007. The field study was conducted within a designated Landscape-protected area near to Kongsvold adjacent to Dovrefjell-Sunndalsfjella National Park. This study site was selected primarily on the basis that it forms part of the network for Monitoring programme for Terrestrial Ecosystems (TOV) in Norway, led by the Norwegian Institute for Nature research (NINA), and concerning, *inter alia,* effects of pollution on plants and animals and chemical and biological monitoring. In this way a large dataset of ancillary information would be available facilitating any subsequent interpretation of results. Furthermore, by connecting this field programme to ongoing studies, associated costs could be reduced.

Eight soil profiles were collected during the field expedition. These profiles were split into an overlying humus layer and thereafter 3 cm (predominantly mineral soil) increments to a depth of 9 cm using a custom-designed soil corer. This was undertaken with a view to enabling analyses of the activity distribution of radionuclides with depth. Baited traps were used in the collection of various rodents including Bank Vole (*Clethrionomys glareolus*) and the Common Shrew (*Sorex araneus*). Plant samples including samples of bilberry (*Vaccinium myrtillus*) and 2 species of lichens (e.g. *Cladonia stellaris* and *Cladonia*) were collected by hand. Finally, samples of two earthworm species (*Lumbricus rubellus* and *Aportectodea caliginosa*) were collected in areas of brown earth using a spade.

A detailed description of the analysis of polonium in the samples is given in Chen et.al. (2001). Briefly, the freeze-dried material (2-10g) was added to a semi-closed glass flask, ^{208}Po and a known amount of stable Pb (5-10mg) added as yield determinants for ^{210}Po and ^{210}Pb respectively. The sample was completely dissolved using a mixture of HNO_3 HCl and H_2O_2, evaporated to near dryness and polonium plated onto silver discs in a weak hydrochloric

solution. The discs were then analysed without delay using solid state PIPS-detectors. The solution remaining after plating onto the Ag-discs were rinsed from remaining traces of polonium using TIOA-extraction in 10M HCl. The aqueous phase containing Pb was set aside for ^{210}Po ingrowth.

RESULTS AND DISCUSSION

Only preliminary data for rodents were available at the time of writing of this paper. When deriving activity concentrations of ^{210}Po for the time of sampling, a simple decay correction procedure cannot be used because the ^{210}Po attributable to the whole body of the rodent samples at the time of analysis is likely to be comprised of activity remaining from the decay of unsupported ^{210}Po and a component arising from ingrowth via ^{210}Pb (between the time of sampling and the time of analysis). Essentially, we can assume that some Pb-210 is present in the samples (organs within the body such as the liver are known to accumulate stable and therefore radioactive lead) and that the in situ decay of this radioisotope is contributing to the activity measured at the time of analysis.

Since only ^{210}Po results were available at the time of writing of this paper, the results reported here (provisionally decay corrected to date of sampling) are of a preliminary nature only. Once the level of ^{210}Pb has been determined for the samples, the unsupported activity concentration for ^{210}Po at the time of sampling can be determined precisely.

The preliminary data exhibit activity concentrations in the range 41 – 88 Bq/kg^{-1} d.w. for bank vole ^{210}Po and 22 – 84 Bq/kg^{-1} d.w. ^{210}Po for the common shrew (Figure 1). The non-parametric Mann-Whitney test has been applied in order to determine whether data ^{210}Po activity concentrations in shrew are statistically different to corresponding data for bank vole. The null hypothesis is that these 2 samples have been taken from a common population so that there is no consistent difference between the 2 sets of data. Since there is no hypothesis concerning whether the mean rank of one population is greater or less than the other, a two tailed test was considered appropriate.

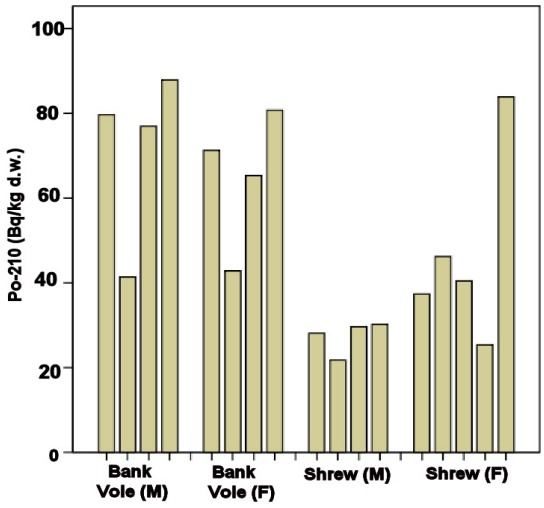

Figure 1. Po-210 activity concentrations in bank vole and common shrew. M= male and F =Female.

Median activity concentrations of ^{210}Po in bank vole (74 Bq/kg d.w.) appear to be significantly different to those determined for shrew (30 Bq/kg d.w.). This is confirmed by the fact that the null hypothesis can be rejected at the $p < 0.008$ level, i.e. the probability that the 2 sets of data come from the same population is extremely low and it is reasonable to conclude that bank vole and shrew ^{210}Po data constitute different populations with different mean ranks.

The dry mass to fresh mass ratio was on average 0.3. This suggests median activity concentrations by fresh mass of approximately 22 Bq/kg f.w. on average for Bank Vole and 9 Bq/kg f.w. for the Common shrew, albeit that these are preliminary determinations. These activity concentrations are considerably higher than the levels reported in Beresford et al., (2007) where an activity concentration of 0.09 Bq/kg f.w. was reported for a category consigned the title "All mammals" and comprising of 32 assorted samples. Whether this discrepancy reflects the preliminary nature of the results presented in this paper, differences (physiology, diet, habitat) between the mammals considered in the aforementioned study and the present study or differences in deposition of ^{210}Pb in this area compared to the aforementioned study, remains a subject for further investigation.

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