Assessment of naturally occurring radionuclides around England and Wales: application of the G-BASE dataset

David G. Jones[1], J Donald Appleton,[1], Neil Breward[1], , Alan C. Mackenzie[1], Catherine Scheib[1], Nicholas A. Beresford[2], Catherine L. Barnett[2], David Copplestone[3]

[1]British Geological Survey (BGS), Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG, UK. [2]Centre for Ecology & Hydrology, CEH-Lancaster, Lancaster Environment Centre Library Avenue, Bailrigg, Lancaster,LA1 UK, [3] Environment Agency, PO Box 12, Richard Fairclough House, Knutsford Road, Warrington WA4 1HG, UK.

INTRODUCTION

A method for impact assessment of ionising radiation on wildlife is being used by the Environment Agency to undertake assessments of Natura 2000 sites in England and Wales. However the contribution that naturally occurring radionuclides make to the radiation dose received by non-human species needs to be determined to compliment the impact assessment methodology.

This paper describes work conducted to assess the background radiation dose rates to non-human biota in terrestrial and freshwater ecosystems in England and Wales concentrating on the derivation of media activity concentration databases. Estimates of activity concentrations of ^{40}K, ^{238}U and ^{232}Th series radionuclides in environmental media (soil, stream sediments and stream waters) have been estimated from total K, U and Th concentrations derived mainly from the ongoing geochemical survey of the United Kingdom (G-BASE), conducted by BGS.

METHODS

For over 35 years the British Geological Survey (BGS) have been conducting a geochemical survey of the UK under the G-BASE project and its precursors (Johnson and Breward, 2004, Johnson et al. 2005). This includes determinations of K, U and Th concentrations in soils, stream sediments and stream waters. The G-BASE sampling procedures are detailed in Johnson et al. (2005). Samples are collected at an optimum density of one every 1.5-2 km^2 for stream sediments and waters and 2 km^2 for soils.. The extent of available data is illustrated for K in Figure 1; coverage for K is similar to that for U and slightly better than that for Th (the total number of samples which have been analysed is: K – 28694, U – 33627, Th - 24567).

As the G-BASE survey has been on-going for many years there have been changes in both analytical procedures and sampling. Both these issues have required normalisation of the data for the purposes of this work. This process if fully described in Beresford et al. (2007). It includes levelling between different analytical techniques and sample types, for example surface and subsurface soils.

The geochemical survey data are currently incomplete across the UK and coverage is different for each sample type. Almost complete coverage was obtained for K in stream sediments (Fig.1a) by combining the BGS data with that of the Wolfson Atlas (Webb et al, 1978). For U and Th in sediments and K, U and Th in soils a more complete coverage (Fig 1b) was achieved by geological extrapolation (i.e. using relationships between soils/sediments and bedrock/superficial geology).

Simplified bedrock and superficial geology codes based on BGS 1: 50 000 scale digital geological maps (see Appleton 2005) were attributed to each soil sample location. Geometric means for each element were calculated for each 1 km grid square and parent material (bedrock plus superficial geology) polygon from the nearest 5 soil sample values for that parent material. These data were then used to compute geometric means for each 25 km^2 (5 x 5 km) grid square using area-weighted geometric mean values for each parent material found in the square (Figure 1 presents data on this basis). This involved summing the products of the mean element content for each 1 km grid square/parent material polygon (derived from the 5 nearest data points on that parent material) and the area of that polygon and dividing the sum of those products by the total area of the 25 km^2 grid square:

$$\sum_{1}^{n} \frac{(\overline{X}_1 Area_1) + (\overline{X}_2 Area_2) + \ldots(\overline{X}n Area_n)}{25km^2}$$

Where $\overline{X}$ is the GM for a 1 km grid square/parent material polygon.

For soils and sediments, spatial datasets were derived for both the (i) geometric mean concentrations from measured samples on a 5x5 km square basis where data are available and (ii) the extrapolated surfaces covering all of England and Wales. For waters, only geometric mean concentrations are provided, where data are available, as relationships between radioelements in waters and geology were not considered sufficiently strong to justify extrapolation.

Specific activities of ^{40}K, ^{232}Th and ^{238}U of 31.6 Bq g^{-1} K, 4.07 Bq mg^{-1} Th and 12.21 Bq mg^{-1} U respectively were used to estimate the activity concentrations of the three radionuclides from the total element concentrations. This assumes secular equilibrium within the ^{238}U and ^{232}Th decay series.

RESULTS

External absorbed dose rates have been estimated for the proposed Reference Animals and Plant (RAP) geometries of the ICRP using the derived media concentrations and dose conversion coefficients from the ERICA Integrated Approach (http://www.ceh.ac.uk/protect/ERICAdeliverables.html). Whilst ^{40}K was the single largest contributor (10^{-2} µGy h^{-1}) to the total dose rates estimated for terrestrial RAP geometries, dose rates estimated for both ^{228}Th and ^{228}Ra were generally within approximately a factor of two of the ^{40}K contribution. Absorbed dose rates for all other radionuclides were at least two orders of magnitude lower than those estimated for ^{40}K. For the rat geometry, exposure whilst underground (assumed to be 50% of the time), dominated the total external absorbed dose rates. External dose rates due to radionuclides below ^{234}U in the ^{238}U series were not estimated.

Internal dose rates for biota in the United Kingdom have recently been reported by the authors (Beresford et al, In press). These were estimated from the results of a literature review and a targeted sampling programme to determine the activity concentration of natural radionuclides found in non-human biota in the United Kingdom. These were found to be in good agreement with those predicted from environmental media using recommended concentration ratios. This gives confidence both in the derived media concentrations data and the concentration ratios.

CONCLUSIONS

The datasets of natural radionuclide concentrations in biota and media will enable significantly improved assessments of the background exposure of non-human species within

England and Wales. The media concentration datasets derived here, together with concentration ratios, could be used to derive background exposure values for reference animals and plants where radionuclide data are lacking.

More complete datasets will be available for environmental media once the G-BASE programme is complete. Other datasets, such as airborne gamma spectrometry, could also be incorporated if more widespread coverage becomes available.

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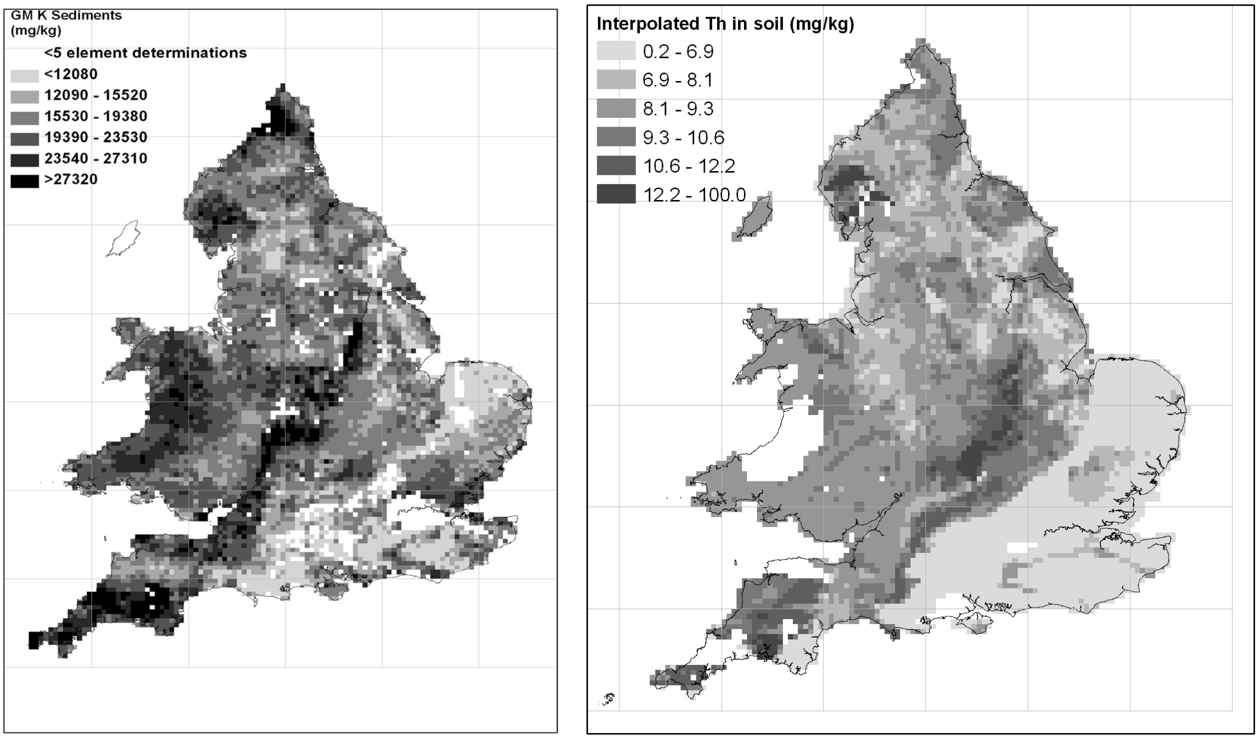

Figure 1 a) Geometric mean (5 x 5 km) for K for stream sediments based on combined BGS and Wolfson Atlas data. b) Concentrations of Th in soils derived by geological interpolation