

Assessment of naturally occurring radionuclides around England and Wales: Application of the G-BASE dataset to estimate doses to non-human species

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Abstract. An assessment of the natural radiation dose to wildlife in England and Wales was made to determine the contribution it may make to the total radiation dose estimated during environmental impact assessments. Significant use was made of systematic datasets for environmental media (stream sediments, stream waters and soils), in particular those produced by the Geochemical Baseline Survey of the Environment (G-BASE) project. This provided extensive, although variable, coverage for different elements and sample types after normalisation of data to account for changes in sampling and analysis over time. Almost complete coverage for K in stream sediments was achieved by merging G-BASE and Wolfson Atlas data. This required normalisation of the Wolfson data to the G-BASE results. Coverage was improved greatly for U and Th in sediments, and K, U and Th in soils, by using the strong relationship between soils and sediments and geology (both solid and superficial) to extrapolate the data. The total U, Th and K data were used to derive activity concentrations of ²³⁸U and ²³²Th series radionuclides and ⁴⁰K. External dose rates to wildlife were then estimated from derived media concentrations; internal dose rates were estimated from measured activities in biota or activities predicted using recommended concentration ratios.

1. 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 [1, 2]. 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 ⁴⁰K, ²³⁸U and ²³²Th series radionuclides in environmental media (soil, stream sediments and stream waters) have been made from total K, U and Th concentrations derived mainly from the ongoing Geochemical Baseline Survey of the Environment (G-BASE), conducted in the United Kingdom by the British Geological Survey (BGS).

2. METHODS

For over 35 years BGS have been conducting a geochemical survey of the UK under the G-BASE project and its precursors [3, 4]. 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. [4]. Samples are collected at an optimum density of one every 1.5–2 km² 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 ongoing 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 is fully described in Beresford et al. [5]. 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 (Figure 1) by combining the BGS data with that of the Wolfson Atlas [6]. Normalisation between the BGS and Wolfson data was achieved through linear quantile transformation for areas covered by both surveys (Figure 2). For U and Th in sediments and K, U and Th in soils, a more complete coverage (Figure 3) was achieved by geological extrapolation (i.e. using relationships between soils/sediments and bedrock/superficial geology).

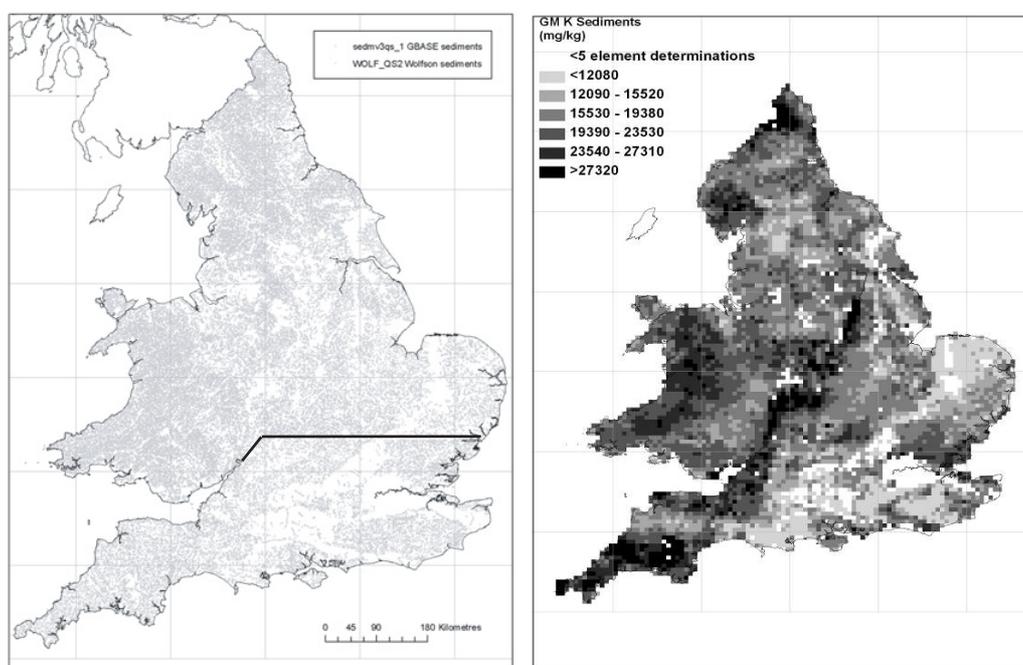


Figure 1. Left: Sample coverage for K in stream sediments with G-BASE samples to the north of the line and Wolfson Atlas samples used to the south. Right: Geometric mean (GM) ($5 \times 5 \text{ km}$) for K for stream sediments based on combined BGS and Wolfson Atlas data.

Simplified bedrock and superficial geology codes based on BGS 1: 50 000 scale digital geological maps [7] 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 ($5 \times 5 \text{ km}$) grid square using area-weighted geometric mean (GM) 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

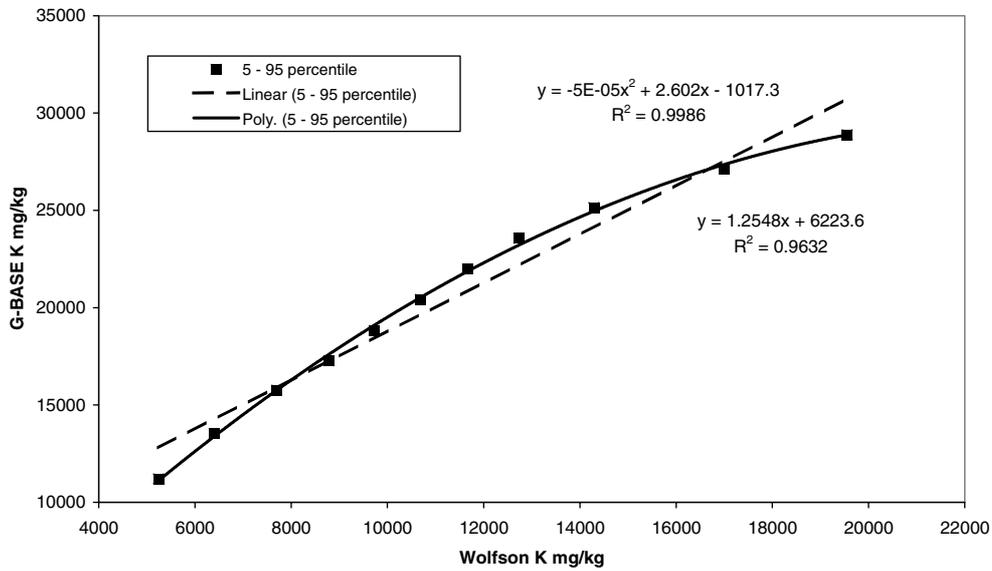


Figure 2. Linear quantile transformation of Wolfson K in stream sediment to GBASE XRF equivalent K in stream sediments (5–95 percentile range; data from this study). The polynomial fit was used for the data transformation.

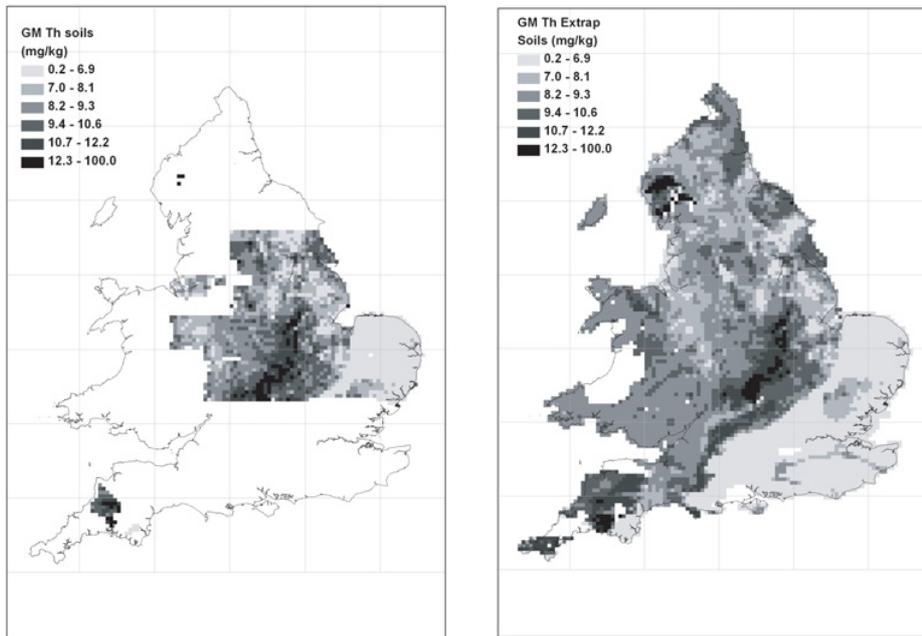


Figure 3. Th in soils (5 × 5 km GM) based on samples (left) and after geological extrapolation (right).

of those products by the total area of the 25 km² grid square:

$$\sum_1^n \frac{(\bar{X}_1 Area_1) + (\bar{X}_2 Area_2) + \dots + (\bar{X}_n Area_n)}{25 \text{ km}^2} \tag{1}$$

Where \bar{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 5×5 km square basis where data are available and (ii) the extrapolated surfaces covering all of England and Wales. For waters, only geometric mean concentrations were derived, where data are available, as relationships between radionuclides in waters and geology were not considered sufficiently strong to justify extrapolation. This means that the data coverage for waters is much more restricted than that for the solid media (Figure 4).

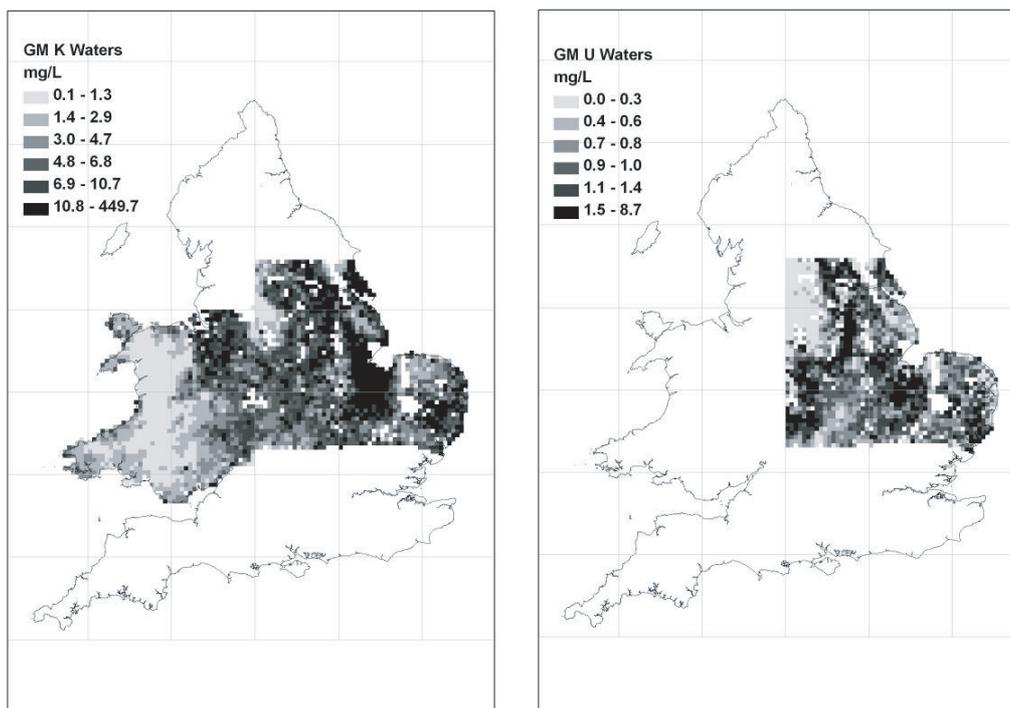


Figure 4. K and U in waters (5×5 km GM) showing more restricted data coverage.

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. It was assumed that all ^{232}Th series radionuclides were in approximate equilibrium. In the case of ^{238}U series radionuclides it was assumed that activity concentrations of ^{234}U , and the intervening decay products were in secular equilibrium with those of ^{238}U ; thereafter, assumptions of equilibrium may not be valid because of the different chemical properties and environmental behaviours of the different elements.

3. APPLICATION OF MEDIA CONCENTRATIONS TO ASSESS DOSE RATES

External and internal dose rates that have been estimated for selected proposed Reference Animals and Plant (RAP) geometries of the ICRP and for terrestrial biota in the United Kingdom have recently been reported by the authors [8]. External dose rates were estimated using the derived media concentrations and dose conversion coefficients from the ERICA Tool [9].

Internal dose rates 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. Measured biota concentrations were found to be in good agreement with those

predicted from environmental media using recommended concentration ratios [5]. This gives confidence both in the derived media concentrations data and the concentration ratios.

Mean total weighted whole-body absorbed dose rates estimated for the selected terrestrial organisms were in the range 6.9×10^{-2} to $6.1 \times 10^{-1} \mu\text{Gy h}^{-1}$. Potassium-40 was the main contributor to both internal and external dose rates.

The water and sediment concentrations together with a literature review, analyses of target fish samples and the ERICA Tool have been used to estimate dose rates to freshwater fish assuming the ICRPs Trout RAP geometry. The radionuclides included in the dose rate estimates were those for which water and sediment concentrations could be derived (e.g. no calculations were made for ^{210}Po and ^{210}Pb). Estimated dose rates for freshwater fish were dominated by internal dose received from ^{40}K with a mean predicted dose rate of $8 \times 10^{-2} \mu\text{Gy h}^{-1}$. Internal dose rates as a consequence of other radionuclides for which it was possible to estimate exposure were of the order $10^{-5} \mu\text{Gy h}^{-1}$; the maximum contributor to external exposure was again ^{40}K with a mean predicted dose rate of $2 \times 10^{-5} \mu\text{Gy h}^{-1}$.

4. CONCLUSIONS

The exploitation of the G-BASE dataset described here gave a unique opportunity to derive an extensive media concentration data set for England and Wales. 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 animals and plants where measurements are lacking.

More complete datasets will be available for environmental media in the future as the G-BASE programme continues. This would allow extrapolated data to be replaced by results from actual samples. Some other, more limited datasets, such as air kerma measurements and soil data for tide washed pastures, were used in the study [5]. Other datasets, such as airborne gamma spectrometry, could also be incorporated if more widespread coverage becomes available.

Acknowledgments

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