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Should we ignore U-235 series contribution to dose?

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ABSTRACT

Environmental Risk Assessment (ERA) methodology for radioactive substances is an important regulatory tool for assessing the safety of licensed nuclear facilities for wildlife, and the environment as a whole. ERAs are therefore expected to be both fit for purpose and conservative. When uranium isotopes are assessed, there are many radioactive decay products which could be considered. However, risk assessors usually assume ^{235}U and its daughters contribute negligibly to radiological dose. The validity of this assumption has not been tested: what might the ^{235}U family contribution be and how does the estimate depend on the assumptions applied? In this paper we address this question by considering aquatic wildlife in Canadian lakes exposed to historic uranium mining practices. A full theoretical approach was used, in parallel to a more realistic assessment based on measurements of several elements of the U decay chains. The ^{235}U family contribution varied between about 4% and 75% of the total dose rate depending on the assumptions of the equilibrium state of the decay chains. Hence, ignoring the ^{235}U series will not result in conservative dose assessments for wildlife. These arguments provide a strong case for more *in situ* measurements of the important members of the ^{235}U chain and for its consideration in dose assessments.

1. Introduction

The mining and milling of uranium ore bodies result in releases of uranium and radioactive decay products to aquatic ecosystems. Although modern effluent controls are efficient, operational releases result in the accumulation of contaminants in near field sediments. Predicting ecological risks in these near field aquatic systems is complicated by the many radioactive daughters of the uranium decay series, and the partitioning of contaminants between water and sediments. Predictive ecological risk assessments are therefore conservative to compensate for data gaps and uncertainties to ensure the protection of the receiving aquatic environment.

It is our current understanding that ecological risks appear to be higher for chemical toxicity than radiological toxicity for natural uranium based on certain assumptions about attainment of secular equilibrium and partitioning of daughters (Mathews et al., 2009). It therefore remains important to refine radiological risk assessment methods to fully characterize the hazardous nature of uranium in a fully integrated manner for all associated contaminants and pathways.

Both wildlife and human radioprotection systems share the concept of additive risk assuming that effects of exposure to radioactivity are linked to the dose, or energy, received by organisms regardless of the radionuclide. In theory such a concept relies upon a complete inventory of radionuclides to which receptors are exposed so that total radiological risk is not underestimated.

Three radioisotopes of uranium are naturally found in the environment: ^{234}U, ^{235}U and ^{238}U. ^{238}U and ^{234}U each represent 49% to the specific activity of natural uranium (Cossonnet et al., 2001) and are generally considered in dose assessments. ^{238}U is the precursor of a radioactive decay chain, producing a long series of radioactive daughters including isotopes such as ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Pb, and ^{210}Po (Fig. 1), that can contribute significantly to dose. As a result, ^{238}U and daughters radionuclides ^{230}Th, ^{226}Ra, ^{210}Po and ^{210}Pb are routinely monitored in the environment, for instance, downstream of decommissioned and operating U mines and mills.

In contrast, Uranium-235 contributes only 2% to the specific activity of natural uranium (Cossonnet et al., 2001), and is generally not explicitly considered in dose assessments, being either ignored or at best estimated from ^{238}U data (the isotopic ratio ^{235}U/^{238}U is

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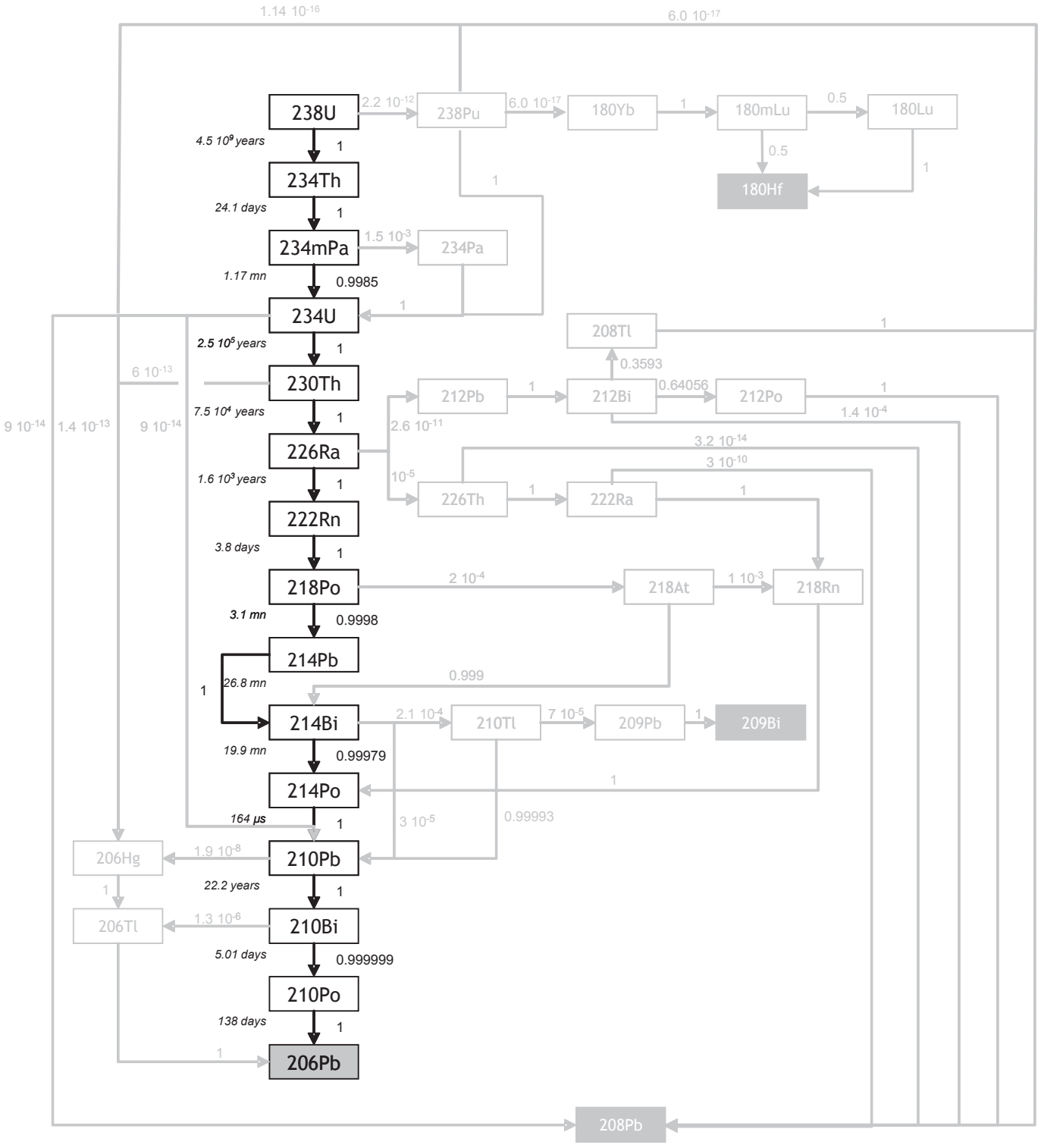

Fig. 1. ^{238}U decay chain (italic text: half-life; normal text: branching ratio (BR); grey lines: secondary decay chain with first daughter BR less than 0.9; solid grey boxes: stable element; Nucleonica GmBH, 2015).

approximately 0.04). ^{235}U is also a precursor of a radioactive decay chain, with seven radioactive daughters that may contribute significantly to dose (^{231}Pa, ^{227}Th, ^{223}Ra, ^{219}Rn, ^{215}Po and ^{211}Bi (Supplementary material Table A1)). However, there are no measured data for components of the ^{235}U decay series in environmental samples, because their analysis methods are complex and costly (Sheppard and Herod, 2012). Instead, radio-ecologists can only estimate the activity of daughter radionuclides in environmental media and in non-human biota by assuming that radionuclide daughters are in a given equilibrium with the parent ^{235}U isotope (which concentration is usually assumed and not measured).

This paper addresses if ignoring ^{235}U series radionuclides is