Impact of gold mining on levels of naturally occurring radionuclides in aquatic ecosystems of the Witwatersrand Basin, South Africa

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For more than a century, uraniferous gold ores have been exploited by various mines in the "West Rand" and "Far West Rand" goldfields located in the catchment area of the Wonderfonteinspruit, south-west of Johannesburg, South Africa. The long-lasting mining-related discharges of naturally occurring radionuclides from point and diffuse sources into the Wonderfonteinspruit catchment area, which forms the eastern catchment of the Mooi River, result in a complex pattern of radioactive contamination of water bodies, sediments and soils throughout the area. As a consequence of the different sources of radionuclides (mine waters and slimes dams), their different geochemical and transport behaviour in the environment, and variations in the source term (intermittent mine water discharges, infrequent seepage water emission, sporadic erosion from slimes dams after heavy rainfalls) a high temporal and spatial variability of the contamination levels and the activity ratios of the various radionuclides in water and sediments/soils was observed.

Activities measured for the ^{232}Th decay chain in water and sediment samples are predominantly low and near to natural background levels. In general, the activity concentration levels in surface waters are dominated by ^{238}U and ^{234}U, which are in secular equilibrium and in natural ratio with the ^{235}U activity, and by ^{226}Ra. At slimes dams, where acidic seepage occurs, elevated activity concentrations of ^{210}Pb and ^{210}Po in water ponds were encountered, indicating specific impacts of acidic seepage from old mining legacies in the long-term. The activity of sediments and (floodplain) soils is dominated by ^{238}U decay chain nuclides, exhibiting distinct spatial variations in activity levels and ratios depending on radionuclide source terms and relevant transport processes and environmental conditions.

In the frame of a radiological impact assessment carried out on behalf of the National Nuclear Regulator of South Africa, incremental effective doses (above the natural background) were calculated for members of the public living in the Wonderfonteinspruit catchment area, based on the South African Licensing Guide LG-1032 and IAEA recommendations. Taking into account realistic exposure scenarios and pathways, potential radiation exposures of the public above the effective dose limit of 1 mSv/a were calculated for various of the investigated sites, with maximum effective doses up to some tens of mSv/a.

LA-MC-ICPMS ^{87}Sr/^{86}Sr analysis on tooth enamel – Pitfalls and problems

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LA-MC-ICPMS on human teeth using ^{87}Sr/^{86}Sr to trace intra-individual mobility has been hampered due to the difficulty in generating reproducible radiogenic Sr ratios. Diagenetic uptake of REE into teeth enamel and Kr in the introductory gases interferes with measurements and are primarily responsible for the analytical difficulties in archaeological samples. Consquently, despite success of LA-MC-ICPMS for biological calcite (Christensen *et al.* 1995, Ramos *et al.* 2004, McCulloch *et al.* 2005), the methodology has not lent itself as readily to analyses of calcium hydroxyapatite.

However, molecular interferences and oxide formation can be eliminated by torch and gas flow manipulation (Foster and Vance 2006), the deviation of ^{84}Sr/^{86}Sr from the natural value of 0.056490 can be used as a qualitative assessment, and the Y intensity can be used as a proxy for REE interferences (e.g. McCulloch *et al.* 2005). The ^{86}Kr contribution to the 86 intensity is usually ~1%, and hence can be discounted as a major influence on the normalized ^{87}Sr/^{86}Sr . A further assessment of accuracy and precision is through shark teeth that routinely yield marine ^{87}Sr/^{86}Sr ratios (0.709167 ± 0.00003). Despite these manipulations, our LA-MC-ICPMS data for human teeth consistently show an offset from the bulk solution MC-ICPMS and TIMS, which we attributed to REE concentration heterogeneity within an enamel layer and between those layers combined with the much lower overall concentration of Sr in those samples.

Our data contributes to the understanding of inherent problems in applying LA-MC-ICPMS to biological apatite such as teeth. We also assess the best method for obtaining reproducible ^{87}Sr/^{86}Sr ratios for whole teeth and intra-tooth ^{87}Sr/^{86}Sr variability using LA-MC-ICPMS, MC-ICPMS, and TIMS.

References

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