Whole-organism concentration ratios in wildlife inhabiting Australian uranium mining environments

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INTRODUCTION

Environmental impact assessments conducted for Australian mine sites involving naturally occurring radioactive material require an assessment of radiation doses to wildlife. Whole-organism concentration ratios ($CR_{wo\text{-}media}$) are pivotal in these assessments as they relate the whole-organism ($_{WO}$) fresh mass radionuclide activity concentration to the activity concentration of that radionuclide in an environmental medium ($_{media}$). Many of the standard biota dose models (e.g., ERICA Tool, ICRP framework; IAEA handbook) now utilise summarised $CR_{wo\text{-}media}$ values from the Wildlife Transfer Database (WTD, http://www.wildlifetransferdatabase.org/) that was developed through recent work within International Atomic Energy Agency (IAEA) EMRAS II programme (Copplestone *et al.* 2013). Whilst Australian data were included in the initial WTD, it comprised a relatively small contribution. Additionally concern has been expressed by some stakeholders in Australia about the suitability of using the default $CR_{wo\text{-}media}$ values in standard biota dose models for Australian wildlife and environmental conditions. The primary reason for this concern lay with the fact that the summarised values were largely derived from northern hemisphere temperate climates, whereas Australia mining sites are located in ecosystems dominated by semi-arid and tropical climates.

To address these issues the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) undertook a review and evaluation of data relating to wildlife inhabiting Australian uranium mining environments that could be utilised to calculate $CR_{wo\text{-}media}$ values (Hirth, 2014). Subsequently, work has been undertaken to correct errors identified in the original Australian data in the WTD, to submit additional data to the WTD and to undertake a more detailed comparison of the Australian $CR_{wo\text{-}media}$ values with the summarised WTD values.

This work also supports the implementation of best-practice standards in environmental radiological assessment in Australia and the *Safety Guide for Radiation Protection of the Environment* that is being prepared by ARPANSA for use by Australian stakeholders.

DATA REVIEW

Data were sourced from scientific journal publications, site-specific reports from mining operators or technical reports from government agencies on former mining areas and areas that now have operational mines or have been the subject of some form of baseline assessment and/or draft Environment Impact Assessment. As the magnitude of $CR_{wo\text{-}media}$ values can vary for different environmental conditions, each of the locations for which data were available were classified with reference to the Australian Bureau of Meteorology modified Köppen classification system and the major seasonal rainfall zones (Hirth, 2014). Major U deposits in Australia fall predominantly into either the arid or semi-arid desert grassland or tropical/sub-tropical grassland areas with summer dominant rainfall.

Much of the data reviewed were not in directly useable formats and required some form of conversion. Prior to ~1980 activity concentrations were reported in pCi requiring, at a minimum, conversion to Bq. A significant amount of data required activity concentrations to be converted to a fresh mass basis and most data were at the tissue level as they were originally collected for the purpose of assessing ingestion doses to humans $CR_{wo\text{-}media}$ values were calculated from measurements on a range of tissues following standard approaches (e.g. Yankovich *et al.* 2010). The Australian datasets incorporated into the WTD when it was first established were reviewed and all calculations checked and revalidated. Corrections to some of these values were subsequently made when additional data was submitted to the WTD in 2013.

The WTD provides summary tables for $CR_{wo\text{-}media}$ values for organism- radionuclide combinations across generic ecosystems (Howard *et al.* 2013). The Australian datasets, once consolidated, were then compared with the summary tables.

RESULTS AND CONCLUSIONS

$CR_{WO\text{-}media}$ values for terrestrial organisms

Seven terrestrial wildlife groups are currently included in the WTD for Australian wildlife. This includes data for U-mining areas for ^{226}Ra, ^{210}Pb, ^{210}Po and isotopes of Th and U (for herbs, grasses, shrubs, trees, reptiles and mammals). Data from the Maralinga nuclear test site for ^{239}Pu, ^{137}Cs and ^{241}Am (for mammals, arthropods and reptiles) were also included and details are discussed elsewhere (Johansen *et al.* 2014; Johansen and Twining, 2010).

When no dry:fresh weight ratios were reported, reference dry:fresh weight ratios for trees and shrubs were initially considered in the absence of anything more appropriate. However, later datasets reported dry:fresh weight ratios for similar species from arid/desert regions of Australia that were consistently and substantially different (average dry:fresh weight ratios in shrub/grass foliage of 0.6) to the assumed values (0.1) used in the WTD. Upon review, where only dry weights were reported, it was decided to delay submitting these CRs to the WTD until appropriate dry:fresh weight ratios could be determined. Similarly, tissue concentration ratios for Th have been previously calculated for some Australian mammals. However, as suitable whole-organism to tissue CRs have not yet been established to convert tissue CRs to whole-organism CRs for Th in mammals, these have not yet been submitted to the WTD.

$CR_{wo\text{-}media}$ values for freshwater organisms

Six freshwater wildlife groups have currently been included in the WTD for Australian wildlife. This includes data from U-mining areas and covers the radionuclides ^{226}Ra, ^{210}Pb, ^{210}Po and isotopes of Th and U (for algae, crustaceans, molluscs, fish, reptiles and vascular plants). Most $CR_{wo\text{-}media}$ values for vascular plants submitted to the WTD reflect $CR_{wo\text{-}sediment}$ rather than the $CR_{wo\text{-}water}$ and are not included in the summary tables as these values are likely to be highly site-specific incorporating transfer processes from sediment to water and from water to biota (Beresford *et al.,* these proceedings).

$CR_{wo\text{-}water}$ values for Ra in molluscs were found to range over four orders of magnitude and showed both seasonal and site (between and within) variation, highlighting the importance of understanding specific site and wildlife (size and age) information.

Comparison with WTD summary values

The work undertaken has resulted in approximately 270 new or revised $CR_{wo\text{-}media}$ values covering terrestrial and freshwater wildlife groups being included in the WTD (through July 2013). The majority of these Australian $CR_{WO\text{-}media}$ values did not present as outliers when compared to the summary values from the WTD. One dataset from an acidic, radioactive tailings storage did present outliers for ^{210}Po CR values and it was agreed to exclude these unusual, highly site-specific values from the WTD. The WTD excludes stable element data from sites with high heavy metal concentrations, at which non-linear transfer may be observed (Copplestone *et al.* 2013). For U-mining areas, co-contamination by a range of metals can often be present when compared to control sites. However the data from mining sites are representative of conditions that are of general radioecological interest and have not been excluded on the basis of high heavy metal concentration.

Additional $CR_{wo\text{-}media}$ values have been calculated and once reviewed for quality assurance they will also be compared with the summary values from the WTD. This will see more than 500 $CR_{wo\text{-}media}$ values consolidated for Australian wildlife and ecosystems.

Conclusions

The study resulted in approximately 270 new or revised $CR_{wo\text{-}media}$ values covering terrestrial and freshwater wildlife groups that are now available for use in assessing radiological transfer uranium mining environments. While these values reflect Australian conditions, in comparing with the WTD summary values the Australian data did not present significant outliers for 95th percentile screening application. It is therefore recommended that the WTD summarised values are appropriate for use in screening level assessments in the absence of any Australian-specific data. However, they should be used with caution in more detailed assessments. This agrees with the recommendation made by Wood *et al.* 2013 that the $CR_{wo\text{-}media}$ approach is used with caution above screening level assessments given the uncertainty in the summarised $CR_{wo\text{-}media}$ values.

Gaps in the Australian datasets remain. For freshwater environments there are no data for phytoplankton, zooplankton, insects, insect larvae or amphibians. For terrestrial environments there are no data for amphibians, annelids, ferns, fungi, lichens & bryophytes. These gaps reflect that most the existing data had been collected in support of human assessments rather than for assessing impact on the environment.

There has also been no examination of marine data in Australia. Whilst the marine environment was not specifically relevant for the U-mining industry review, other industries have been subject to radiological environmental assessments (e.g. gas and petroleum extraction activities) which have, to date, been entirely dependent on the summary values. This may be an area that requires examination in the future.

This analysis provides key data for input that may be applied to U- mining sites in general, but also provide a more sound basis for implementing the draft *Safety Guide* document which encourages use of site-specific, or similar ecosystem-specific $CR_{wo\text{-}media}$ values when possible.

ACKNOWLEDGEMENT

ARPANSA wishes to acknowledge the Australian Government Department of Industry for their financial support of the review project. Input of N.A. Beresford was facilitated through NERC-CEH National Capability funding.

REFERENCES

Beresford, N.A., D. Copplestone, A. Hosseini, J.E. Brown, M.P. Johansen, G.A. Hirth, S. Sheppard, W. Dagher, T.L. Yankovich, S. Uchida, J. Napier, C. Wells, B.J. Howard, C.L. Barnett and M.D. Wood. 2014. Recent development of wildlife transfer databases. These proceedings.

Copplestone, D., Beresford, N.A., Brown, J., Yankovich, T. 2013. An international database of radionuclide Concentration Ratios for wildlife: development and uses. J. Environ. Radioact. 126, 288-298 http://dx.doi.org/10.1016/j.jenvrad.2013.05.007

Hirth, G., 2014. A review of existing Australian radionuclide activity concentration data in non-human biota inhabiting uranium mining environments. Australian Radiation Protection and Nuclear Safety Agency Technical Report No. 167. http://www.arpansa.gov.au/pubs/technicalreports/tr167.pdf

Howard, B.J., N.A. Beresford, D. Copplestone, D. Telleria, G. Proehl, S. Fesenko, R.A. Jeffree, T.L. Yankovich, J.E. Brown, K. Higley, M.P. Johansen, H. Mulye, H. Vandenhove, S. Gashchak, M.D. Wood, H. Takata, P. Andersson, P. Dale, J. Ryan, A. Bollhöfer, C. Doering, C.L. Barnett and C. Wells, 2012. The IAEA handbook on radionuclide transfer to wildlife. J. Environ. Radioact. 121, 55-74 http://dx.doi.org/10.1016/j.jenvrad.2012.01.027

Johansen, M.P., D.P. Child, E. Davis, C. Doering, J.J. Harrison, M.A. Hotchkis, T.E. Payne, S. Thiruvoth, J.R. Twining, and M.D. Wood, 2014. Plutonium in wildlife and soils at the Maralinga legacy site: persistence over decadal time scales. J. Environ. Radioact. 131, 72-80 http://dx.doi.org/10.1016/j.jenvrad.2013.10.014

Johansen, M.P. and J.R. Twining, 2010. Radionuclide concentration ratios in Australian terrestrial wildlife and livestock: data compilation and analysis. Radiat. Environ. Biophys. 49, 603-611

Wood, M.D., N.A. Beresford, B.J. Howard and D. Copplestone, 2013. Evaluating summarised radionuclide concentration ratio datasets for wildlife J. Environ. Radioact. 126, 314-325 http://dx.doi.org/10.1016/j.jenvrad.2013.07.022

Yankovich, T.L., N.A. Beresford, M.A. Wood, T. Aono, P. Andersson, C.L. Barnett, P. Bennett, J.E. Brown, S. Fesenko, J. Fesenko, A. Hosseini, B.J. Howard, M.P. Johansen, M.M. Phaneuf, K. Tagami, H. Takata, J.R. Twining and S. Uchida, 2010. Whole-body to tissue concentration ratios doe use in biota dose assessments for animals. Radiat. Environ. Biophys. 49, 549-565