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Modelling the dispersion of radon-222 from a landform covered by low uranium grade waste rock

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ABSTRACT

The dispersion of ^{222}Rn from the planned remediation of the Ranger U mine in the wet-dry tropics of Northern Australia was modelled. Dry and wet season contour maps of ^{222}Rn dose normalised to ^{226}Ra activity concentration in the proposed waste rock substrate on the remediated landform were developed. Three example exposure scenarios were assessed based on an anticipated waste rock ^{226}Ra activity concentration of 800 Bq kg^{-1}. The estimated above-background annual dose from ^{222}Rn to hypothetical receptors at the Aboriginal community at Mudginberri (~10 km NNW) was 0.005 mSv and at the township of Jabiru (~7 km W) was 0.033 mSv. The estimated above-background annual dose for the hypothetical worst case scenario, representing a receptor 1 km WNW of the landform centroid during the dry season and at the centroid during the wet season, was 0.13 mSv. Variability analysis on the 20 y meteorological dataset used in the dispersion modelling showed that the dry and wet season ^{222}Rn dose predictions in any single year could be approximately double those of an average year, which suggests that estimates of average ^{222}Rn dose should potentially be doubled if the assessment aim is to demonstrate compliance with the public dose limit.

1. Introduction

The Ranger U mine is located within the Alligator Rivers Region in the seasonal wet (November–April) and dry (May–October) tropics of Australia's Northern Territory (Fig. 1). The mine is scheduled to cease operating by 2021 and be remediated by 2026 after approximately 40 y of mining and milling activities. The planned remediation of the mine will result in a final landform covered by waste rock and vegetation (Energy Resources of Australia, 2018). The remediation objective is to establish an environment similar to the adjacent World Heritage protected area of Kakadu National Park such that the final landform could be incorporated into the park (Commonwealth of Australia, 1999). There must also be minimum restrictions on the use of the area because of radiological conditions (Commonwealth of Australia, 1999).

Waste rock is excavated material with U concentrations uneconomical for processing but generally higher than typical background levels. Consequently, the final landform is expected to be characterised by elevated activity concentrations of ^{238}U decay series radionuclides compared to background and higher than background ^{222}Rn exhalation fluxes.

^{222}Rn is an inert radioactive gas ($t_{½} \approx 3.8$ d) produced from the decay of ^{226}Ra in the ^{238}U decay series. The alpha decay of ^{226}Ra naturally present in soils and rocks (including waste rock) can eject the newly formed ^{222}Rn atom from the mineral lattice to the pore space through a process called emanation. The ejected ^{222}Rn atom can then move through the pore space by diffusion and enter the atmosphere through a process called exhalation. These two processes (i.e. emanation and exhalation) and the factors influencing them have been described elsewhere (Ishimori et al., 2013; Porstendörfer, 1994). Once in the atmosphere, ^{222}Rn is primarily dispersed by turbulent air mixing (Porstendörfer, 1994). Dose from exposure to ^{222}Rn primarily arises from its short-lived ($t_{½} < 30$ min) radioactive progeny (^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po), which deposit in the lungs and deliver a dose to the lung tissue upon decay (ICRP, 2010).

The Aboriginal community at Mudginberri is located approximately 10 km NNW of the Ranger U mine. People from the community are potentially most at risk of above-background ^{222}Rn exposure after the mine is remediated, as they may camp or hunt along traditional routes that could take them on or near the final landform. Another group of people that could potentially be exposed to ^{222}Rn from the final landform are residents of the town of Jabiru, located approximately 7 km W of the mine. The town was established to support the development of the mine and is scheduled to be decommissioned when the mine closes, though a final decision on its future has not yet been made.

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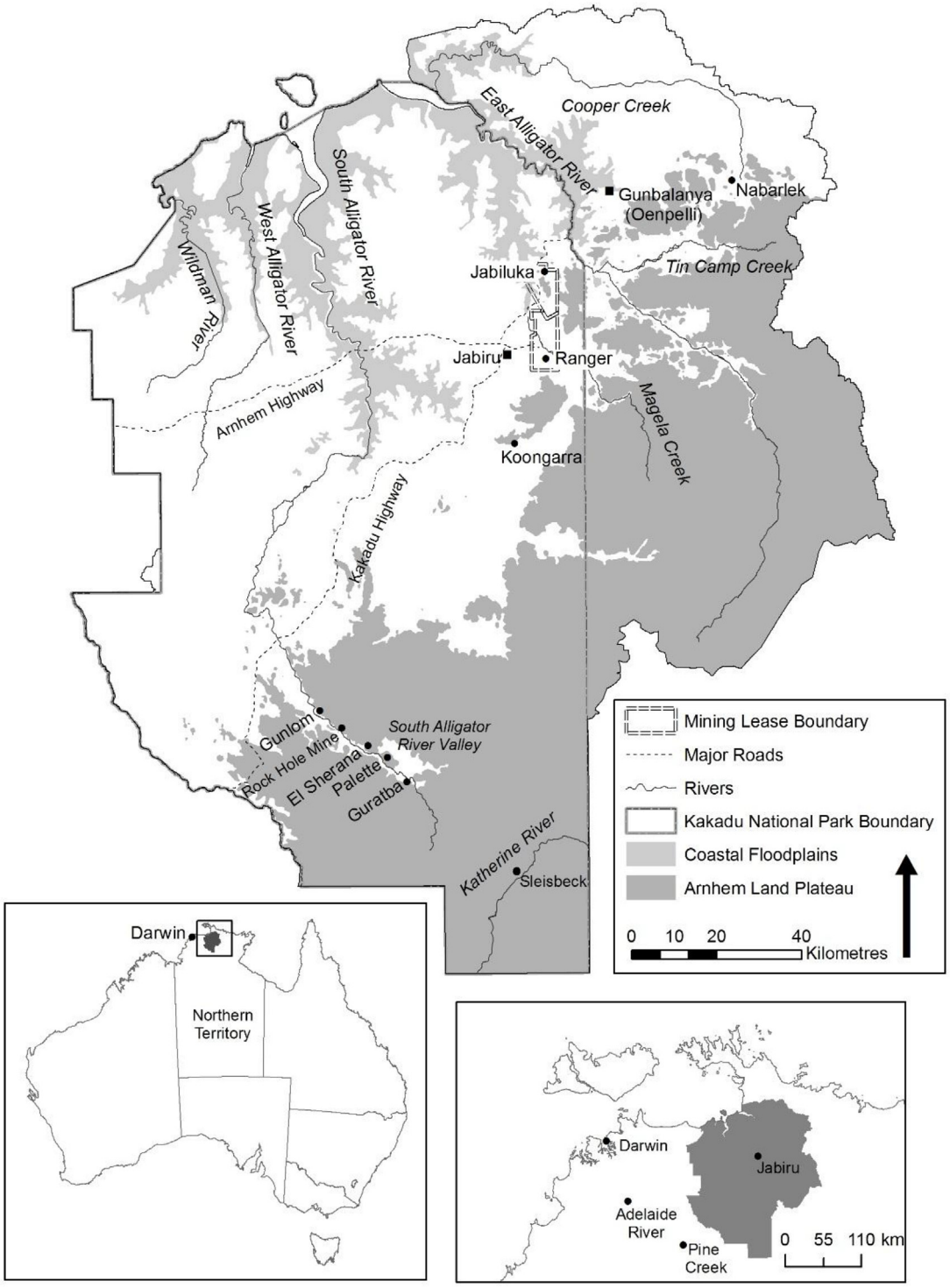

Fig. 1. Alligator rivers region.

The aim of this study was to model the dispersion of ^{222}Rn from the final landform and develop contour maps for estimating ^{222}Rn doses to the public. The study supplements previous work on characterising ^{222}Rn exhalation fluxes from waste rock (Bollhöfer and Doering, 2016) and forms part of a broader assessment of radiation exposure pathways (Doering et al., 2017) to determine whether doses to the public from the final landform are likely to exceed the statutory dose limit of 1 mSv in a year.

2. Methods

RESRAD-OFFSITE 3.2 (Gnanapragasam and Yu, 2015) was used for ^{222}Rn dispersion modelling in which Gaussian plume dispersion is used to calculate the transport of ^{222}Rn from a source to offsite areas. The parameter settings used are given in Table 1. The modelling was based on a conceptual landform (Fig. 2) (Lowry et al., 2015) with an area of 848 ha (Lowry, pers. comm.). The conceptual landform was gridded into 1 ha cells (Fig. 2) to accurately represent its shape in the modelling (RESRAD-OFFSITE 3.2 can only model ^{222}Rn dispersion from square or