Assessment of Non-Human Biota Dose at the El Amin University Proposed Site, Minna, Nigeria

M. Gomina (mahmoudgomina@yahoo.com)[1], M. T. Kolo[2], O. I. Olarinoye[2], M. Bashir[1], I. K. Suleiman[1] & A. S. Gene[1]

[1]Department of Physics, Ibrahim Badamasi Babangida University Lapai, Nigeria

[2]Department of Physics, Federal University of Technology Minna, Nigeria

Abstract

Previous measurements of environmental radioactivity have been focused mainly on impacts on humans. However, in recent years, increased emphasis has been placed on assessing the radioactive impact on non-human biota. This is in recognition that human protection may be insufficient to assure environmental protection. The necessity to safeguard non-human biota against ionizing radiation prompted the development of a variety of models and methodologies (such as RESRADBIOTA, ERICA tool, DosDiMEco, LIETDOS-BIO) for dose and risk assessments. In this study, the ERICA model has been adopted to determine the dose to non-human biota for the first time at the El Amin University proposed site in Minna, North central Nigeria. The initial radiological assessments of the soil in the area have revealed potential dose risk to humans, with maximum specific activities of 152.60 and 185.9 Bq/kg for ^{226}Ra and ^{232}Th respectively. These activities were used as input data in the ERICA model, in order to ensure that maximum possible value of dose rates to non-human biota was below the screening dose rate criterion of 10 μGy/h. Dose rates to non-human terrestrial biota computed, varied from 0.29 μGy/h (for tree) to 16.69 μGy/h (for lichen and bryophytes), while the dose rates for non-human aquatic biota varied from 0.002 μGy/h (for mammal) to 36.329 μGy/h (zooplankton). The results obtained could serve as a baseline data for the assessment of possible anthropogenic enhancement of the total dose rate to non-human biota of the study area.

Keywords: *Environmental radioactivity, Gamma dose rates, Ionizing radiation, ERICA dose assessment tool, Maximum specific activity*

Introduction

Exposure to radiation is inevitable. Natural gamma-emitting radionuclides such as ^{238}U, ^{232}Th along with their progenies, and ^{40}K are omnipresent in the environment (Pulhani *et al.*, 2005).

In soil, they are present in varying concentrations, depending on the nature of the weathered parent rock. Their presence in soil represents the main external sources of exposure (Petrovic *et al*., 2018; UNSCEAR, 2010). Soil-plant-man and soil-plant-animal-man are two major pathways for the transfer of radionuclides to humans. The transfer from soil to plants occurs along with nutrients during mineral uptake. Thus, they accumulate in various parts and even reach the edible portions (Pulhani *et al*., 2005). Animals, typically herbivores, consume the edible sections, which are then consumed by humans. As a result, radioactive contamination continues to spread throughout the food chain.

The data obtained from the radiological survey of soil worldwide are dominated by dose assessments to humans (Petrovic *et al*., 2018). This is because previous measurements of environmental radioactivity have been focused mainly on impacts on humans. However, in recent years, increased emphasis has been placed on assessing the radioactive impact on non-human biota, recognizing that human protection may be insufficient to assure environmental protection (Sotiropoulou *et al*., 2016; ICRP, 2003). The necessity to safeguard non-human biota against ionizing radiation prompted the development of a variety of models and methodologies (such as RESRADBIOTA, LIETDOS-BIO, DosDiMEco, ERICA tool) for dose and risk assessments (Vives i Batlle *et al*. 2007; Beresford *et al*., 2008; Howard and Larsson, 2008 IAEA 2012; Petrovic *et al*., 2018).

In Nigeria, the radiation dose to humans due to natural radioactivity levels in the terrestrial and aquatic environments have been investigated (Jibiri, 2001; Kolo, 2014; Njinga *et al*., 2015; Babatunde, 2015; Isinkaye and Emelue, 2015; Aladeniyi *et al*., 2019; Joel *et al*., 2019; Akpanowo *et al*., 2020; Mbonu and Ben, 2021). However, limited information is available concerning the exposure levels of non-human biota. Therefore, the present study aims to assess the radiological impact on non-human biota due to NORM in the El Amin University proposed site in Minna, Northcentral Nigeria.

Materials and Methods

Study area

The proposed site for the El Amin University is situated in Minna, the capital city of Niger State in Northcentral Nigeria. The study area is off the city's eastern bypass, near the M. I. Wushishi Housing Estate and one of the tributaries of River Chanchaga runs through the study area, as shown in Figure 1.

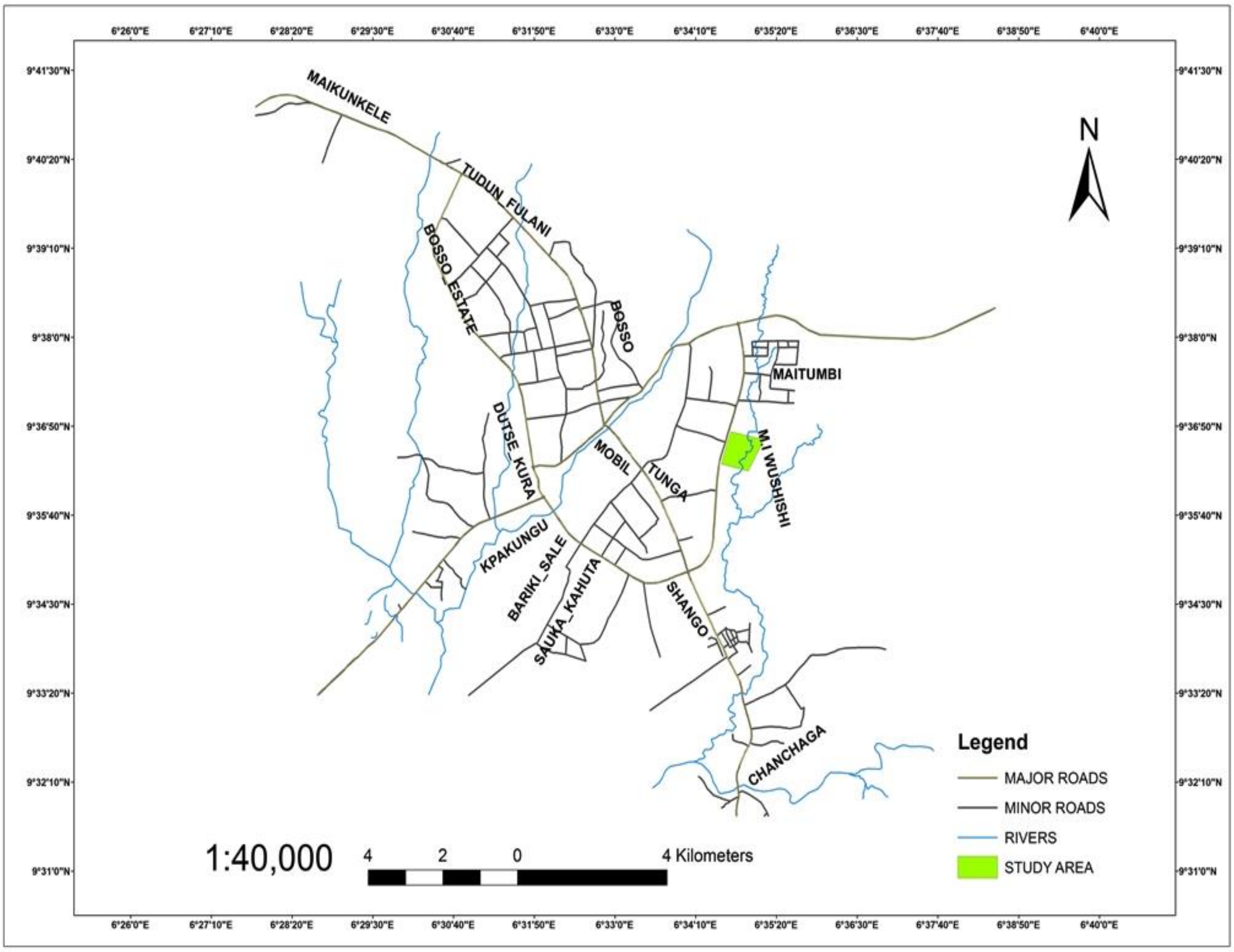

Figure 1: Location map of the study area (Gomina *et al*., 2019)

Dose assessment

ERICA assessment tool (version 1.3, May 2019 update) was used to estimate dose rates to default terrestrial and aquatic reference organisms in Tables 1 and 2 respectively. Natural radioactivity levels around the study area have been assessed and published by Gomina *et al.* (2020). For this study, the ERICA tool's Tier 2 was utilized. In order to guarantee that the greatest potential value of non-human biota dose rates are lower than the screening dose rate requirement of 10 μGy/h, the maximum measured specific activity of the two major contaminant radionuclides (^{226}Ra and ^{232}Th) in soil were used as input data in the model (Petrovic, 2018). At Tier 2, the Default Uncertainty Factor (UF) of 3 was chosen to account for the uncertainties in the assessment procedure. An UF = 3 will test for a 5% possibility of surpassing the dosage screening value, according to the definition of the ERICA tool software system, assuming that the risk quotient distribution is exponential (ERICA, 2019). Using the provided data, dose rates are computed using DCCs, dose conversion coefficients in μGy/h per Bq/kg fresh weight, and weighting factors of 10.0 for α, 3 for low β and 1 for (high energy) β and γ radiation. A number of research provide information about the ERICA tool and its uncertainties (Brown *et al*., 2008, 2016; IAEA 2014; Larsson 2008; Oughton *et al*. 2008; Petrovic, 2018; Radioecology Exchange, 2020).

Results and Discussion

Results for terrestrial and aquatic non-human biota obtained from the ERICA dose assessment tool are shown in Tables 1 and 2 respectively. For the terrestrial biota, the dose rates vary from 0.295 μGy/h (for Tree) to 16.687 μGy/h (for Lichen & Bryophytes). The higher contribution to the total dose rates per organism derived from exposure to ^{226}Ra as shown in Figure 2 conforms to previous results (Cujic and Dragovic, 2017; Giwa *et al.,* 2018; Petrovic *et al.,* 2018).

Table 1: Dose to terrestrial non-human biota

Organism	Ra-226 Dose Rate (μGy/h)	Th-232 Dose Rate (μGy/h)	Total Dose Rate (μGy/h)
Amphibian	1.048	0.002	1.050
Annelid	1.038	0.039	1.077
Arthropod – detritivorous	1.039	0.022	1.061
Bird	0.842	0.002	0.844
Flying insects	0.953	0.022	0.975
Grasses & Herbs	3.796	0.684	4.480
Lichen & Bryophytes	15.058	1.629	16.687
Mammal – large	0.968	0.001	0.969
Mammal - small-burrowing	1.043	0.001	1.044
Mollusc – gastropod (snail)	1.045	0.039	1.084
Reptile	1.037	0.009	1.046
Shrub	6.916	0.261	7.177
Tree	0.289	0.005	0.294

As the results in Table 1 demonstrate, the total dose rates to terrestrial reference organisms are below the ERICA (2019) screening dose rates of 10 μGy/h, except for Lichen and Bryophytes with a dose rate of about 1.6 times the non-effect threshold. This implies that the Lichen and Bryophytes are the most exposed organisms. Similar results have been reported in literature (Cujic and Dragovic, 2017; Petrovic *et al*., 2018). However, the result of the present study is not an indication that Lichen and Bryophytes are necessarily the most at risk since they are the least sensitive to radiation exposure in comparison to other non-human terrestrial biota (Hosseini *et al*., 2011; Petrovic *et al*., 2018).

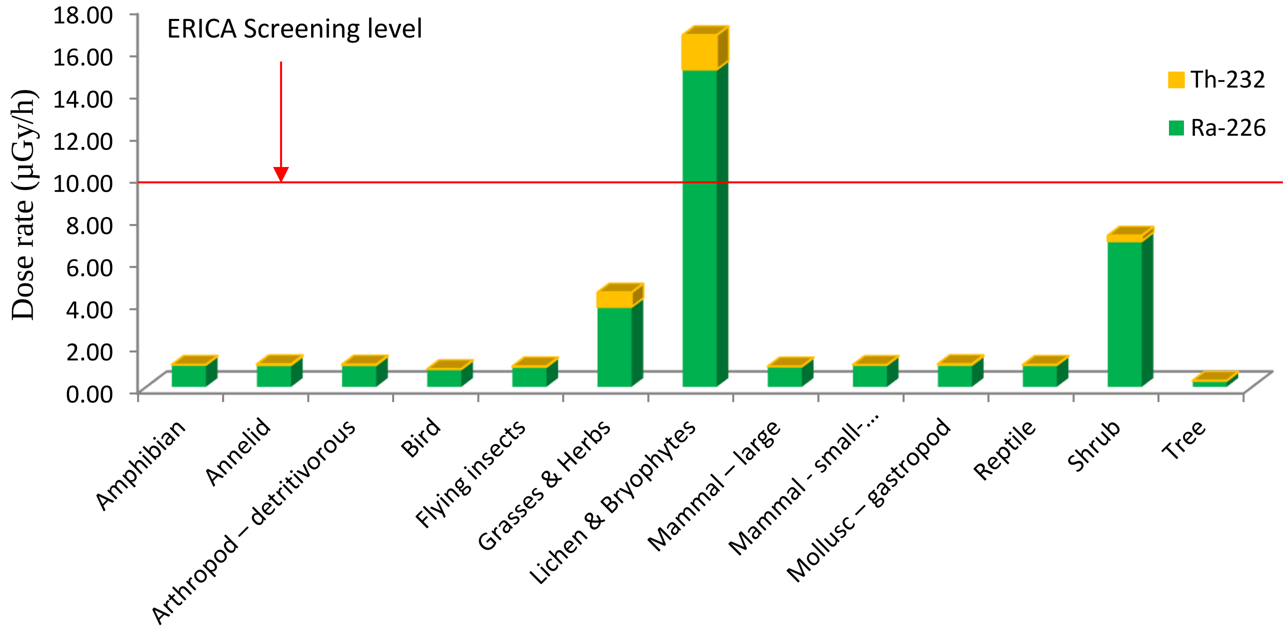

Figure 2: ERICA Dose rates for non-human Terrestrial biota

Table 2: Dose to aquatic non-human biota

Organism	Ra-226 Dose Rate (µGy/h)	Th-232 Dose Rate (µGy/h)	Total Dose Rate (µGy/h)
Amphibian	9.220	0.001	9.221
Benthic fish	0.351	0.001	0.352
Bird	9.786	0.001	9.787
Crustacean	0.503	0.001	0.504
Insect larvae	36.527	0.001	36.528
Mammal	0.001	0.001	0.002
Mollusc – bivalve	35.739	0.003	35.742
Mollusc – gastropod	35.747	0.002	35.749
Pelagic fish	0.281	0.001	0.282
Phytoplankton	0.828	0.003	0.830
Reptile	1.226	0.001	1.227
Vascular plant	1.744	0.021	1.765
Zooplankton	36.328	0.001	36.329

For the non-human aquatic biota, the minimum dose rate was recorded for Mammal (0.002 µGy/h), with a maximum of 36.528 µGy/h recorded for Insect larvae. This is similar to the results for Svyatoye and Perstok lakes by Pungkum (2012). As shown in Table 2, the ^{232}Th dose rates are negligible for aquatic non-human biota. However, the ^{226}Ra and total dose rates for zooplankton, mollusc-gastropod, mollusc-bivalve and insect larvae exceed the ERICA dose screening level as illustrated in Figure 3. Thus, indicating that the organisms' exposure to ^{226}Ra may be sufficient to cause radiation-induced effects.

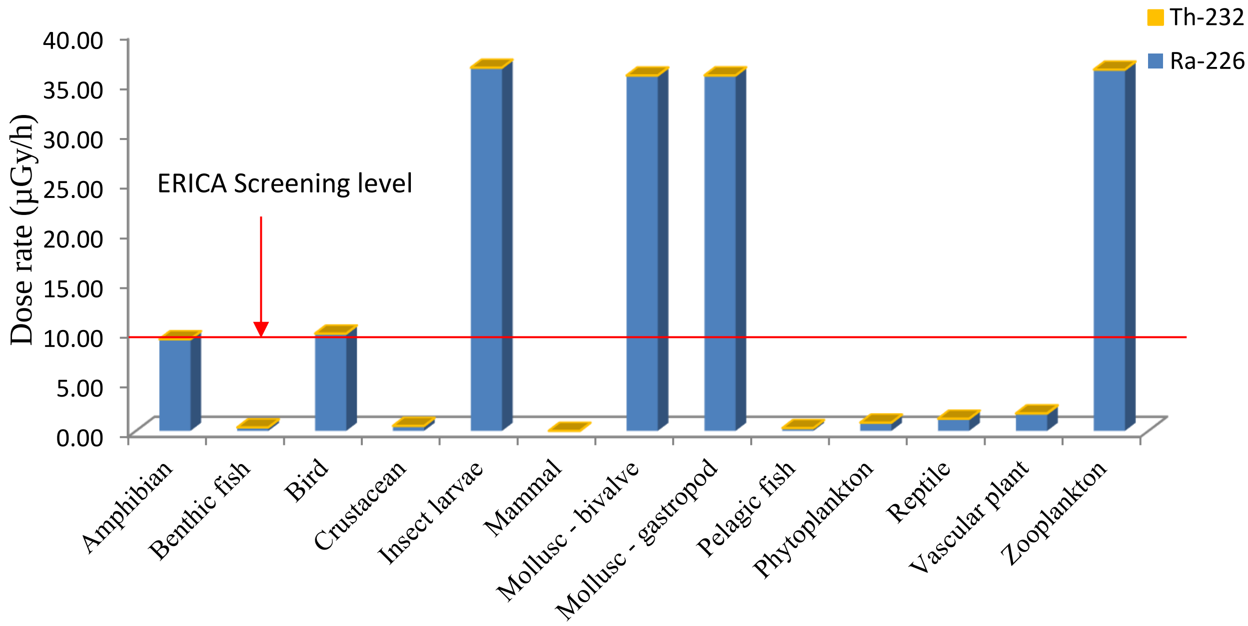

Figure 3: ERICA Dose rates for non-human aquatic biota

Conclusion

The ERICA dose rates of the non-human biota investigated indicate exposure to low levels of ionizing radiation. Despite the recorded dose rates for Lichen & Bryophytes, Insect larvae, Mollusc-bivalve, Mollusc gastropod, and Zooplankton that are well above the 10 µGy/h ERICA dose screening level, no significant effects were observed. However, the findings could be relevant in future research into the effects of long-term low-level ionizing radiation on non-human biota within El Amin University community, Minna Metropolis, and environs. While the ERICA Tool is mostly a generic model, it can yield more precise results in terms of the radiological dose rates of the considered ecosystem when actual measurements are included. This could aid decision-making in terms of a more holistic approach to environmental impact assessment policies.

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