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Evaluation of natural radioactivity in soil, sediment and water samples of Niger Delta (Biseni) flood plain lakes, Nigeria

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ABSTRACT

This paper presents the findings of a baseline study undertaken to evaluate the natural radioactivity levels in soil, sediment and water samples in four flood plain lakes of the Niger Delta using a hyper pure germanium (HPGe) detector. The activity profile of radionuclides shows low activity across the study area. The mean activity level of the natural radionuclides ^{226}Ra, ^{232}Th and ^{40}K is 20 ± 3, 20 ± 3 and 180 ± 50 Bq kg^{-1}, respectively. These values are well within values reported elsewhere in the country and in other countries with similar environments. The study also examined some radiation hazard indices. The mean values obtained are, 76 ± 14 Bq kg^{-1}, 30 ± 5.5 ηGy h^{-1}, 37 ± 6.8 μSv y^{-1}, 0.17 and 0.23 for Radium Equivalent Activity (Ra_{eq}), Absorbed Dose Rates (D), Annual Effective Dose Rates (E_{ff} Dose), External Hazard Index (H_{ex}) and Internal Hazard Index (H_{in}) respectively. All the health hazard indices are well below their recommended limits. The soil and sediments from the study area provide no excessive exposures for inhabitants and can be used as construction materials without posing any significant radiological threat to the population. The water is radiologically safe for domestic and industrial use. The paper recommends further studies to estimate internal and external doses from other suspected radiological sources to the population of the Biseni kingdom.

1. Introduction

Natural environmental radioactivity and the associated external exposure due to gamma radiation depend mainly on the local geological and geographical conditions and appear at different levels in each region in the World (UNSCEAR, 2000). The natural terrestrial gamma dose rate is an important contributor to the average dose received by the world's population (Tso and Leung, 2000; Senthilkumar et al., 2010). Estimation of the radiation dose distribution is vital in assessing the health risk to a population and serves as a reference for documenting changes in environmental radioactivity due to anthropogenic activities (Obed et al., 2005). Monitoring for radioactive materials are therefore of primary importance for humans, organisms and for environmental protection, but rapid and accurate methods for the assay of radioactivity is essential (El-Bahi, 2004).

When outdoors, humans are exposed to natural terrestrial radiation that originates predominantly from the upper 30 cm of the soil (Chikasawa et al., 2001). Humans are also exposed by contamination of the food chain which occurs as a result of direct deposition of radionuclides on plant leaves, root uptake from contaminated soil, sediment or water (Arogunjo et al., 2004), and from direct ingestion of contaminated water (Avwiri and Agbalagba, 2007). To assess these exposures, radioactivity studies have been previously carried out in soil and sediment samples in other parts of the world, some similar to those in Nigeria (e.g. Selvasekarapandian et al., 2005; Kannan et al., 2002; Kirchner et al., 2002; Al-Junda et al., 2003; Avwiri et al., 2005; Nour and Abdel, 2005; Obed et al., 2005; Patra et al., 2006; Diab et al., 2008; Senthilkumar et al., 2010) and in water samples (Onoja, 2004; Avwiri et al., 2005, 2007 and Avwiri and Agbalagba, 2007).

This present study assesses the specific activities and examines some of the radiation hazard indices of these naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) in soil, sediment and water samples from four flood plain lakes in the Niger Delta region of Nigeria, using γ-ray spectrometry. The flood plains, lakes and other River Niger tributaries of the region have been vulnerable to oil spill pollution, oil related effluent discharges, gas flare and other anthropogenic activities, which may enhance the natural radioactivity level of the area and human exposure. The values reported in this study constitute a baseline for radioactivity in the study area as no such study has been carried out in this flood plain before.

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Table 1
Activity concentrations of natural radionuclides (Bq kg^{-1} DW) in soil samples from the Niger Delta flood plain (Biseni).

Location	Sample size	^{226}Ra		^{232}Th		^{40}K	
		Mean	Range	Mean	Range	Mean	Range
Aboh	5	29 ± 4.1	(16–40)	33 ± 6.3	(19–46)	410 ± 82	(360–530)
Akpide	5	25 ± 3.7	(17–26)	20 ± 4.4	(14–28)	220 ± 62	(170–300)
Egbedidi	5	17 ± 3.0	(12–21)	18 ± 3.6	(15–23)	98 ± 22	(69–130)
Esiribi	5	20 ± 2.4	(11–23)	15 ± 3.2	(12–19)	110 ± 31	(100–140)
Mean		**18 ± 3.4**		**22 ± 4.4**		**210 ± 49**	

2. Materials and methods

2.1. Description of study area

The Niger Delta of Nigeria is situated in the Gulf of Guinea between latitudes 3° and 6° N and longitudes 5° and 8° E. It is the largest delta in Africa, rich in hydrocarbons, with an area of about 7500 km^2. The geology of the study area has been reported elsewhere (Taiwo and Tse, 2009).

The long shallow lakes subject to this report are found in the lower flood plain area of the delta. This area is flooded during the rainy season (March–October) with annual precipitation from 2500 to 3000 mm (NDES, 2000). Lake Aboh (05°14.5′ N, 06°32.5′ E), Lake Akpide (05°16.4′ N, 06°32.4′ E), Lake Egbedidi (05°15.5′ N, 06°32.5′ E) and Lake Esiribi (05°18.48′ N, 06°31.5′ E) are situated within the Biseni kingdom in Bayelsa State, Nigeria. The lakes are located in rain forest ecosystems and are rich in biodiversity despite being threatened by recent frequent oil and gas pollution (Manilla and Nwachuku, 2009). They all have their source from the River Niger and have the River Nun basin as their drainage area. Lake Esiribi is the biggest of the four lakes and is a sacred lake rich in crocodiles. Lake Aboh is adjacent to oil and gas exploration and production activities owned by the Nigeria Agip oil company.

These lakes and plains are of immense value to the Biseni kingdom and the Niger Delta region in general. They serve as sources of water for drinking and domestic purposes, as fishing grounds, transport routes and the plains are used for farming.

2.2. Sample collection and preparation techniques

Five samples each of soil, sediment and water were collected in each of the flood plain lakes to provide a total of sixty samples.

The bulk soil samples (stones, vegetation and organic debris removed) were collected in undisturbed, uncultivated grass covered level areas and in locations remote from man-made structures such as roads and buildings to minimize any potential external influence on results (Senthilkumar et al., 2010). Each soil sample was a composite collected in a black polythene bags from five sample locations, each of about 200 cm^2, within an area of approximately 100 m^2. The samples were collected to a depth of 10–15 cm which represents the soil depth variation given the purpose of the study and the soil characteristics (soil permeability) in the four flood plain areas. The soil samples were then oven dried at 60–80 °C for about 24 h. The dried samples were ground with mortar and pestle and then passed through a 100 μm mesh sieve and weighed. In order to achieve radioactive equilibrium between ^{226}Ra and its progenies, the soil samples were packed in a 250 mL plastic container (a standard geometry) and stored for a period of four weeks for ingrowth.

Sediment samples were collected at the bottom of the lakes from different sampling points using a 15 mm steel geological auger, which was cleaned prior to use with acid, detergent and rinsed with tap water. The samples were wrapped in aluminum foil, labeled and then placed into black polythene bags for easy transportation to the laboratory. Water content was determined by decantation after settling. Further sample preparation techniques follow the procedure reported above for soils.

Five, 2 L water samples (combining 1 L from the surface and 1 L at the mid-depth) were collected in each lake for this study. The water was collected at 50 m intervals close to the shoreline where there is less dilution of the washout from the plains and the surrounding environment. Water samples were collected in plastic bottles and samples were acidified with 11 M HCL at the rate of 10 mL per liter of sample immediately after sample collection to avoid adsorption of radionuclides onto the walls of the containers (Onoja, 2010). Marinelli beakers of 1 L capacity, previously washed, rinsed with dilute H_2SO_4 and dried to avoid contamination, were filled with known volumes (~500 mL) of the water sample. The beakers were subsequently firmly sealed for at least four weeks to ensure no loss of radon and that thereby a state of secular equilibrium was reached between radium isotopes and their respective daughters (Onoja, 2010). Each sample was then counted using gamma spectroscopy as follows.

2.3. Gamma-ray detection system

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the samples were measured using a coaxial HPGe detector, model GC3018–7500SL (serial number 693085, Canberra GMbH, Germany). The relative efficiency of the detector is 30% and it has a resolution of 1.8 keV at 1.33 MeV. The detector was maintained in a vertical position in a lead cylindrical shield of 10 cm thickness. The detector was coupled to a computer through a preamplifier base (Model 2002 CSL, Canberra GMbH, Germany).

Table 2
Activity concentrations of natural radionuclides (Bq kg^{-1} DW) in sediment samples from Niger Delta flood plain lakes (Biseni).

Location	Sample size	^{226}Ra		^{232}Th		^{40}K	
		Mean	Range	Mean	Range	Mean	Range
Aboh	5	38 ± 7.2	(29–46)	38 ± 6.4	(34–40)	500 ± 79	(470–530)
Akpide	5	29 ± 4.4	(24–36)	30 ± 3.7	(27–37)	260 ± 60	(250–290)
Egbedidi	5	18 ± 2.8	(16–21)	22 ± 2.9	(19–24)	120 ± 53	(110–130)
Esiribi	5	15 ± 2.6	(13–17)	15 ± 3.2	(12–19)	100 ± 58	(96–110)
Mean value		**25 ± 4.4**		**22 ± 4.4**		**220 ± 63**	