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Radiological safety assessment and determination of heavy metals in soil samples from some waste dumpsites in Lagos and Ogun state, south-western, Nigeria

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ABSTRACT

Assessment of naturally occurring radionuclides and heavy metals in 5 major dumpsites around Lagos and Ogun State, Nigeria, was carried-out to determine the natural radionuclide and heavy metals in the dumpsites and to evaluate the hazards these may have on the public. Radionuclide concentrations were determined using gamma-ray spectrometry with NaI (Tl) detector. The mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the soil samples were 23.1 ± 2.5, 35.1 ± 2.1 and 318.9 ± 27.4 Bq kg^{-1}, respectively in Ojota, 32.1 ± 6.1, 44.2 ± 16.0 and 377.4 ± 9.0 Bq kg^{-1} in Ojo, 18.2 ± 4.8, 28.4 ± 3.1 and 340.9 ± 12.1 in Igando, 26.3 ± 9.0, 38.1 ± 1.1 and 531.1 ± 23.0 in Agbara and 15.3 ± 3.6, 22.3 ± 1.7 and 840.9 ± 42.0 in Ogijo, respectively. The results of ^{226}Ra and ^{232}Th are lower than the world average but higher for ^{40}K (UNSCEAR, 2000). The analysis of the heavy metal concentrations indicated that there is presence of Cadmium, Zinc and Copper in high proportion. These metals are toxic and may cause severe problem with prolonged exposure. Monitoring the accumulation of these metals in soil samples is very important and the practice of cultivating the land for planting vegetables and legumes by farmers around the dumpsites must be discouraged to prevent the transportation of these toxic metals into human system.

1. Introduction

The earth is naturally radioactive, and about 90% of human radiation exposure arises from natural sources such as cosmic radiation, exposure to radon gas and terrestrial radionuclides (Lee and Lee, 2005). The most common terrestrial radionuclides that produce gamma-rays are member of the ^{238}U and ^{232}Th series and ^{40}K, and their concentrations vary considerably depending on the soil type and local geology.

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Human activities create wastes and the way that these are handled, stored, collected and disposed can give rise to impacts on the environment and public health. Hazardous waste can cause pollution, damage to health and even death. The environmental problem posed by solid wastes has been of concern to federal, state and local authorities in Nigeria. Poor waste management poses several challenges to the well-being of city residents due to the potential of the waste to pollute water, food sources, land, air and vegetation (Njoroge, 2007), when the wastes are not properly managed or disposed (Porteous, 1985). Industrialization and population growth result in changes in the composition and quality of waste generated as can be seen in most cities in developing countries, of which Nigeria is one (UNIDO, 2001).

At dumpsites there are possibilities for radiation to be emitted due to the presence of radioactive waste in the landfills as well as naturally occurring radionuclides in the soil. The radioactive contamination of soil, water and air can be transferred to human through the soil via plants (^{40}K) or through inhalation (^{222}Rn and ^{220}Rn). These radionuclides even at low concentrations can have potential impacts on the environmental quality and human health and may pose a long term risk. Various studies have been carried out in recent years in Nigeria and elsewhere to investigate radioactivity in dumpsite (Odunaike, Laoye, Alausa, Ijeoma, & Adelaja, 2008; Ogundare and Alabi, 2008; Okoronkwo, Odemelam, & Ano, 2006; Oladapo, Oni, Olawoyin, Akande, & Tijani, 2012). Radioactivity measurements have also shown the existence of traces of radionuclide in the staple foods consumed in Nigeria. It was revealed that staple food stuffs consumed in Nigeria contain traces of radionuclide (Akinloye and Olomo, 2005; Jibiri, Farai & Alausa, 2007) and as a result of this, refuse dumpsites were identified as a liable recipient in containment of radioactive materials. Farmers cultivate and plant legumes, vegetables, etc in the field around the dumpsites, so the transportation of heavy metal as well as radionuclides in soil from this sites are possible via root-uptake and then to human through breathing and ingestion. Therefore, it is necessary to carry out an accurate measurement of elemental and radionuclide composition in soil sample from these dumpsites.

The aims of this study were to measure the natural radionuclides present in representative soil samples from dumpsites by gamma-ray spectrometry using a NaI (Tl) detector; to estimate the hazard indices from these dumpsites to the general public and to determine the elemental composition of the soil samples. This study was carried out in 5 different dumpsite locations around Lagos and Ogun state, south-western Nigeria. These dumpsites are Ojota (Olusosun Landfill), Ojo (Scrap Yard), Igando (Solous III), Ogijo (Metalfrique Landfill) and Agbara industrial estate dumpsite in Lagos state. These dumpsites cover about 5 ha of land and have been in existence for over 20 years. Wastes in these dumpsites were mostly generated from domestic and industrial wastes from pharmaceuticals, medical, breweries, distilleries, cement, beverages, aluminum roofing sheet and iron and steel companies. Infectious medical wastes, scrap metals and industrial toxic wastes are also disposed together in the dumpsites especially in Ojo Scrap yard and Agbara Industrial Estate dumpsite.

2. Materials and method

2.1. Sample collection and processing

Soil samples were collected from active sites at each dumpsite. 10 soil samples were collected from each dumpsite. The samples were collected to a depth of about 20–30 cm at the various points using auger and about 20 m away from each sampling point. The samples were processed following standard procedures (EML, 1983). Soil samples were well mixed, weighed and then dried in an oven at 105 °C overnight and reweighed to find the water content. The samples were crushed and sieved through a 0.2-mm sieve. Sieved samples were weighed and a mass of 200 g of each sample was placed in a non-radioactive plastic container. The plastic containers were hermetically sealed with adhesive tape (AERB, 2003) for over a month for secular equilibrium to take develop (Olomo, Akinloye, & Balogun, 1994).

2.2. Experimental methods

Analysis for radionuclide concentrations was performed by gamma-ray spectrometry using a sodium iodide detector. The counting assembly was a scintillation detector and a Canberra multi-channel analyzer. The detector was a 7.6 × 7.6 cm^2 NaI (Tl) manufactured by Bicron. A cylindrical lead shield of thickness ~5 cm with a fixed bottom and a movable cover shielded the detector from background radiation. The spectrometer was tested for its linearity and then calibrated for energy using gamma sources supplied by the International Atomic Energy Agency, Vienna. This was achieved by collecting spectra data from standard sources with energies ranging from 0.511 to 2.62 MeV. The channel numbers of the photopeaks corresponding to the different gamma energies were recorded after 900 s and the energy-channel linear relationship was drawn. The detection efficiency calibration of the system was carried out using a reference standard gamma source prepared by Rocketdyne Laboratories, Canoga Park, CA, USA, which is traceable to a mixed standard gamma source (ENV94084-200 g) by Analytic Inc., Atlanta, GA, USA. The detector assembly has a resolution of ~8% at 0.662 MeV of ^{137}Cs. The reference sources have activity concentration of 479.15, 566.47 and 11.60 Bq kg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th, respectively. The background count was determined by counting an empty container of the same dimensions as the one containing the samples and subtracting from the gross count. The counting time was set at 36 000 s (10 h) to obtain the gamma spectrum with good statistics.

From the net area, the activity concentrations in the samples were obtained using Eq. (1):

$$A\left(\text{Bq kg}^{-1}\right) = kCn \tag{1}$$

where $k = 1/\varepsilon\, P_\gamma\, M_s$,

A is the activity concentration of the radionuclide in the sample given in Bq kg^{-1}, Cn is the count rate under the corresponding peak, ε is the detector efficiency at the specific γ-ray energy, P_γ is the absolute transition probability of the specific γ-ray, and M_s is the mass of the sample (kg).