Radiological Assessment of Soils on the Waysides of the Road Underconstruction in Ijebu-Ode, Ogun State, Southwestern Nigeria

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Abstract

The ongoing road construction and rehabilitation of major highways in Ijebu-Ode involved the grading, refilling of the roads with different types of soils and the use of various materials that may be radioactive. Therefore the construction and the rehabilitation of the roads may lead to enhancement of the natural radioactivity levels in the area. Soil samples were collected from the sideways of the roads and analysed using a single crystal 0.51cm x 0.51cm NaI (Tl) detector, manufactured by Scintitech Instrument, USA, is coupled through a Hamamatsa (R1306NSV3068) photomultiplier tube to a Multichannel Analyser, MCA (2100R:01) manufactured by Price gamma Technology, USA. The activity concentrations in the entire area of study were 396.1 ± 70.9 Bqkg^{-1}, 17.7 ± 4.6 Bqkg^{-1}, and 33.9 ± 6.7 Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th respectively. The absorbed dose rate and the outdoor effective dose rate were 27.6 ± 5.5 nGyh^{-1}and $33.9 \pm 6.7 \mu$Svy^{-1} respectively. The collective health detriment was 1.1×10^{-4}. The radiological health effect on the populace in the area were insignificant as the results showed very low radioactivity levels and collective health detriment indicated that 11 out of 100,000 people were vulnerable to any type of cancer.

Keywords: Impact assessment, natural radioactivity, road constructions, health detriment, Nigeria

1. Introduction

Radioactivity occurs when unstable nuclei spontaneously disintegrate by emitting nuclear particles and energy in order to attain stability. Among the nuclear particles emitted in the process of radioactivity are the heavy charged α-particles (He^{++}) and the light β-particles (e^{+} or e^{-}) together with neutral and much lighter particles called neutrinos. The natural sources of radioactivity are either terrestrial sources (primordial radionuclides) or extra-terrestrial sources (cosmic rays). Radiation exposure received by individuals in the environment from the primordial sources is known to constitute about 85% of the natural background radiation (IAEA, 1996; Obed et al, 2005, UNSCEAR, 2000). Over 60 radionuclides are found in nature, and they are classified into three general categories- Primordial-formed before the creation of the earth, Cosmogenic- formed as a result of cosmic ray interactions, Artificial radionuclides– formed due to human activities (Eyebiokin, et. al. 2005). The process of nucleo-synthesis in stars forms the primordial radionuclides (terrestrial background radiation). Some of the primordial radionuclides including ^{40}K, ^{87}Rb, ^{232}Th, ^{235}U, and ^{238}U, have their half-lives roughly exceeding the age of the earth. The natural environmental gamma radiation, especially from the series ^{232}Th and ^{238}U radionuclides and their decay products; and the non-serial ^{40}K radionuclide represent the main external source of radiation exposure to the human body. The radioactivity levels are related to the activity concentrations of the decay series of ^{238}U and ^{232}Th and non-series ^{40}K radionuclides in the parent rocks from which the soils originate (Ajayi, et. al., 2008). An essential feature of soil is its ability to accumulate and retain over long periods radionuclides introduced into the environment from the external sources (Jibiri, et. al.,2009).The soil that retains radioisotopes in varying amounts is the major source of continuous exposure of man to either internal or external ionising radiation (Olomo, 2006).

Higher radiation levels are associated with igneous rocks, such as granite and lower levels with sedimentary rocks. There are exceptions, however, as some shale and phosphate rocks have a relatively high content of radionuclides (Alaamer, 2008)

The knowledge of radionuclide distribution and radiation levels in the environment is important for assessing the effects of radiation exposure due to both terrestrial and cosmogenic sources.

Artificial man-made radioactivity is emitted by nuclear power plants, industrial plants, and research facilities. The emissions due to artificial radioactivity are very small in normal operations; however a large quantity of radioactivity can be released to the environment through accidents and dumping of radioactive waste in a particular environment. At times contribution of long-lived decay and activation products from nuclear weapon tests and/or nuclear facilities (mainly ^{137}Cs) add to the natural contribution.

The area under investigation, Ijebu Ode metropolis is the commercial nerve center of the Ijebu geopolitical area of Ogun State. It lies in latitude 6° 49′ north of the equator and longitude 3° 56′ east of the Greenwich Meridian with an elevation of 68m and enjoys a tropical climate with distinct wet season that spans from March/ April through October with a short break in August (August break) and the dry season from November through

February/March (Omotosho, 1988).   The average rainfall is between 40mm and 60mm and the average temperature between 25^0 C and 27^0 C. The study area is in the sandy Abeokuta formation which happens to be the oldest formation underlain by the basement complexwith a characteristic granite base (Rahaman, 1988). It is well known that granites contain high concentrations of uranium, thorium and potassium (Lopez *et al.*, 2004; Yan *et al.*, 2005). The uranium and thorium are incorporated into the rocks in the crystallisation of the last magmas and residual solutions since their large ionic radii hinder them from crystallising in the early silicates (Shiva Prasad *et al.*, 2008).

Based on the Nigerian Population Census (FRNOG 2006) and the population growth estimate of 3.2%, the population figure of the residents in the metropolis was estimated at 192031 and the daily influx of people from neighbouring towns and villages for commercial trade purposes was simulated as over twenty thousand.

The metropolis is being witnessed construction of feeder roads and rehabilitations of major highways in the last two years. The road construction works in the city may enhance the natural radioactivity levels in the study area. In addition, materials that may be radioactive may be used for the construction. Any drop of waste from the materials along the waysides may constitute exposure to the populace in the study area. Thus, it is necessary to:
  i.   measure the activity concentration of the soil on the waysides in the study area.
  ii.   determine the radiological implication on the individuals in the area.

2. Material and Methods

2.1 Soil sampling

Soil samples were collected from waysides of the roads under construction or rehabilitation. A total of thirty (30) samples was collected and the separation distance between the sampling points was 200m to 300m. Nine (sampling points 1-9) samples were collected along Folagbade road, Five (sampling point 10-14) along Ejinrin road, five (sampling point 15-19) along AdeolaOdutola road, six (sampling 20-25) along Ondo road and five (sampling point 26-30) along OkunAwwaw road. Only a few sampling points were shown in Figure 1. At each sampling point, soil was collected to a depth between 150mm and 200mm below the wayside surface. The soil sample was then packed in polythene bags, labeled and taken to Radiation and Health Physics Laboratory at LadokeAkintola University of Technology Ogbomoso for preparation and spectrometry measurements.

2.2 Sample preparation

In the laboratory, the soil samples were oven dried at a steady temperature of 110^0C until the masses of the samples remain constant. The oven dried soil samples were thoroughly crushed, and pulverized. The powdered soil samples were sieved with a 2mm sieve to attain the same matrix with the reference standard soil sample from Rocketdyne Laboratories, California, USA which is traceable to a mixed standard gamma source (Ref. No. 48722-356) by Analytic Inc., Atlanta Georgia. 200gm each of the powdered soil samples was packed into a clean and radon- impermeable plastic container of uniform size and sealed for a period of about 30 days to allow for secular equilibrium between ^{226}Ra and ^{228}Ra and their respective gaseous progenies prior to gamma spectroscopy. The standard reference soil sample was packed in a container of the same material and dimension to those used to pack the powder soil samples so as to ensure constant geometric configuration.

2.3 Radioactivity measurements

The soil samples were analysed using a single crystal 0.51cm x 0.51cm NaI(Tl) detector, manufactured by Scintitech Instrument, USA, is coupled through a Hamamatsa (R1306NSV3068) photomultiplier tube to a Multichannel Analyser, MCA (2100R:01) manufactured by Price gamma Technology, USA. It does not require any internal PC interface slot or special memory reservations. The MCA 2100R includes Quantum MCA software for qualitative analysis. The MCA 2100R performs an automatic adjustment of the detector bias and amplifier gain. All calibration functions were made through the software. The detector has an energy resolution (FWHM) of about 6.2% 0f 0.662MeV (^{137}Cs) which is considered enough to distinguish the gamma ray energies of interest in the present study. The activity concentration of ^{214}Bi determined from its 1.760MeV γ-ray peak was chosen to provide an estimate of ^{226}Ra (^{238}U) in the sample, while that of the daughter radionuclide ^{208}Tl, determined from its 2.615MeV γ-ray was chosen to estimate for ^{232}Th. The ^{40}K radionuclide was determined by measuring the 1.460MeV γ-ray emitted during its decay. Each soil sample container was placed on top of the detector housed tightly inside a shield and counted for a period of 36000 seconds. Equation (1) shows the relationship between activity concentration and the count rate under the photo peak (Jibiri et al 2007, Ademola 2008).

$$C = \frac{C_n}{\varepsilon_P I_\gamma m_s}$$

(1)

where C is the activity concentration of the radionuclide in the sample (Bqkg^{-1}); C_n is the count rate under the photo peak, ε is the detector efficiency at the specific γ-ray energy, I_γ is the absolute transition probability of

specific γ-ray and M_s is the mass of the sample (kg). With the aid of the Quantum MCA software, the activity concentration of each sample was obtained. The detection limits (DL) of 21.3Bqkg^{-1}, 9.1Bqkg^{-1} and 4.9Bqkg^{-1} for ^{40}K, ^{226}Ra and ^{232}Th respectively were also obtained. The values that were lower than the detection limits in the present study were considered as below detection limit (BDL) of the detector. One-half of the detection limits, DL value was considered for calculating the mean activity concentration and other radiological assessments whenever the concentration of any radionuclide was below the detection level, (Mlwilo, et al., 2007).

2.4 External absorbed dose rates

Absorbed dose rate is the most important parameter used when considering the radiation risk to a biosystem (Jibiri and Bankole, 2005). The external absorbed dose rate, D (nGy h−1) in air at 1 m above the ground level for soil containing the concentrations of the radionuclides measured in the samples is calculated using the following equation (UNSCEAR, 2000)

$$D = a. C_K + b. C_{Ra} + c. C_{Th} + d. C_{Cs} \qquad (2)$$

where C_k, C_{Ra}, C_{Th} and C_{Cs} are the concentrations of the ^{40}K, ^{226}Ra, ^{232}Th and ^{133}Cs respectively. UNSCEAR (2000) recommended **a** as 0.43×10^{-10}Gy h^{-1}/Bq kg^{-1}, **b** as 4.27×10^{-10}Gy h^{-1}/Bq kg^{-1}, **c** as 6.62×10^{-10}Gy h^{-1}/Bq kg^{-1} and **d** as 0.30×10^{-10}Gy h^{-1}/Bq kg^{-1}.

2.5 Outdoor effective dose rate

The outdoor effective dose to the members of the population, is dependent on two important factors were considered. The first is a factor that converts the absorbed dose rates (Gy h^{-1}) in air to human outdoor effective dose rates (Sv y^{-1}), while the second factor gives the proportions of the total time for which the typical individual is exposed to outdoor radiation. The United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR, 2000) has recommended 0.7 SvGy^{-1} as the value of the first factor and 0.2 for the outdoor occupancy factors. This second factor implies that the average individual spends only 4.8 h (about 5 h per day) outdoors. The effective dose rate resulting from the absorbed dose rate values was calculated using the relation:

$$E_{ext} = TfQD_{ext}\varepsilon \qquad (3)$$

where E_{ext} is the effective dose rate (μSv y^{-1}), T is the time being 8766 h y^{-1}, f is the outdoor occupancy factor that corrects for the average time spent outdoors (0.2), Q is the quotient of the effective dose rate (0.7 SvGy^{-1}), ε is a factor converting nano (10^{-9}) into the micro (10^{-6}), and the text is the absorbed dose rate in air (nGy h^{-1}).

2.6 Collective effective dose (Man. Sv)

The population size is very important in any epidemiological study that determines the actual number of people suffering the health effect. This was determined using equation 4. That is

$$S_E = E_{ext} \times N \qquad (4)$$

where S_E (measured in Man.Sv) is the collective effective dose
E_{ext} is the outdoor effective dose rate, N is the population size

2.7 Collective health detriment

The linear non threshold (LNT) model was adopted in the study. The model assumes that the number G of individuals suffering a type of cancer (collective health detriment) is directly proportional to the collective dose, S_E. That is:

$$G = RS_E \qquad (5)$$

where R is the proportionality constant called the risk factor and S_E is the collective effective dose

3.1 Result and Discussions

The activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th have been measured in five different roads under construction in Ijebu- Ode, the commercial nerve center of the Ijebu Division of Ogun State. The range and mean activities of each of the natural radionuclides are presented in Table 1. As shown in the table, the wayside along Folagbade road exhibited highest ^{40}K and ^{226}Ra concentration values of 442.6±68.8 and 20.6±4.7 respectively among the roads. This may be owing to the construction of the flyover that involved the use of different kind of materials that may contain element of radioactive materials. The highest mean activity concentration ^{232}Th was measured as 6.3±5.4 Bqkg^{-1} along Adeola road. The mean activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th measured in the entire soils from all the roads were 396.1±70.9 Bqkg^{-1}, 17.7± 4.6 Bqkg^{-1} and 33.9±6.7Bqkg^{-1} respectively. These valves were 5.7%, 44.7% and 15.3% lower than the world average values of 420 Bqkg^{-1}, 32 Bqkg^{-1} and 40 Bqkg^{-}

[1] for ^{40}K, ^{226}Ra and ^{232}Th respectively.

The specific activities of the ^{40}K, ^{226}Ra and ^{232}Th were used in equation 2 to determine the absorbed dose rates. The range and mean absorbed and effective dose rates are also presented in Table 1. The mean absorbed and effective dose rates obtained as shown in the Table 1 were 27.6 ± 5.5nGyh^{-1} and $33.9\pm6.7\mu$Svy^{-1} respectively. The mean absorbed dose rate was less than one-half of the world average value of 59nGyh^{-1} (UNSCEAR, 2000) and the effective value was about one-tenth of the world average value of 0.30mSvy^{-1} (Ademola, 2008).

Using equation 4 and the population estimate of 192031, the collective effective dose for the entire study area was calculated as 6.5×10^{-3} Man. Sv.

The collective health detriment was calculated as 1.1×10^{-4} which translated to eleven (11) in every one hundred thousand (100,000) people are vulnerable to suffer a kind of cancer in the study area.

Conclusion

The activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in the entire area ranged from 261.3-536 Bqkg^{-1}, 11.0-28.2 Bqkg^{-1} and BDL-14.2 Bqkg^{-1}. The results showed that the radioactivity levels in the study area were low when compared with other studies and the world average value. The result indicated that there were no serious health effects on the local population outdoors.

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Table 1: Activity concentrations of radionuclides, absorbed and effective doses in the soils from the study area.

Sampling points		^{40}K (Bqkg^{-1})	^{226}Ra (Bqkg^{-1})	^{232}Th (Bqkg^{-1})	Absorbed dose (nGyh^{-1})	Effective dose (µSvy^{-1})
Folagbade	Range	354.7-536.9	15.8-28.2	BDL-13.4	25.0-36.9	30.6-45.3
	Mean±σ	442.6±68.8	20.6±4.7	3.7±3.6	30.3±5.0	37.2±6.2
Ejinrin	Range	333.0-410.1	14.1-26.4	BDL-10.8	24.1-33.8	29.6-41.5
	Mean±σ	385.7±27.8	18.9±5.5	4.4±4.3	27.4±9.8	33.6±4.7
Adeola	Range	296.5-492.0	11.0±21.5	BDL-14.2	21.8-39.7	26.8-48.8
	Mean±σ	379.9±71.8	15.5±4.1	6.3±5.4	27.3±8.9	33.5±8.9
Ondo	Range	284.3-490.6	13.1-20.2	BDL-12.1	19.5-33.1	23.9-40.1
	Mean±σ	388.4±67.6	16.1±2.5	4.1±3.9	26.3±4.7	32.2±5.7
OkunAwwaw	Range	261.3-446.1	9.3-21.6	BDL-10.8	16.9-30.7	20.7-37.7
	Mean±σ	346.5±83.8	16.0±5.4	4.2±3.7	24.5±9.3	30.1±8.0
Entire Area	**Range**	**261.3-536.9**	**11.0-28.2**	**BDL-14.2**	**16.9-39.7**	**22.3-48.7**
	Mean±σ	**396.1±70.9**	**17.7±4.6**	**33.9±6.7**	**27.6±5.5**	**33.9±6.7**
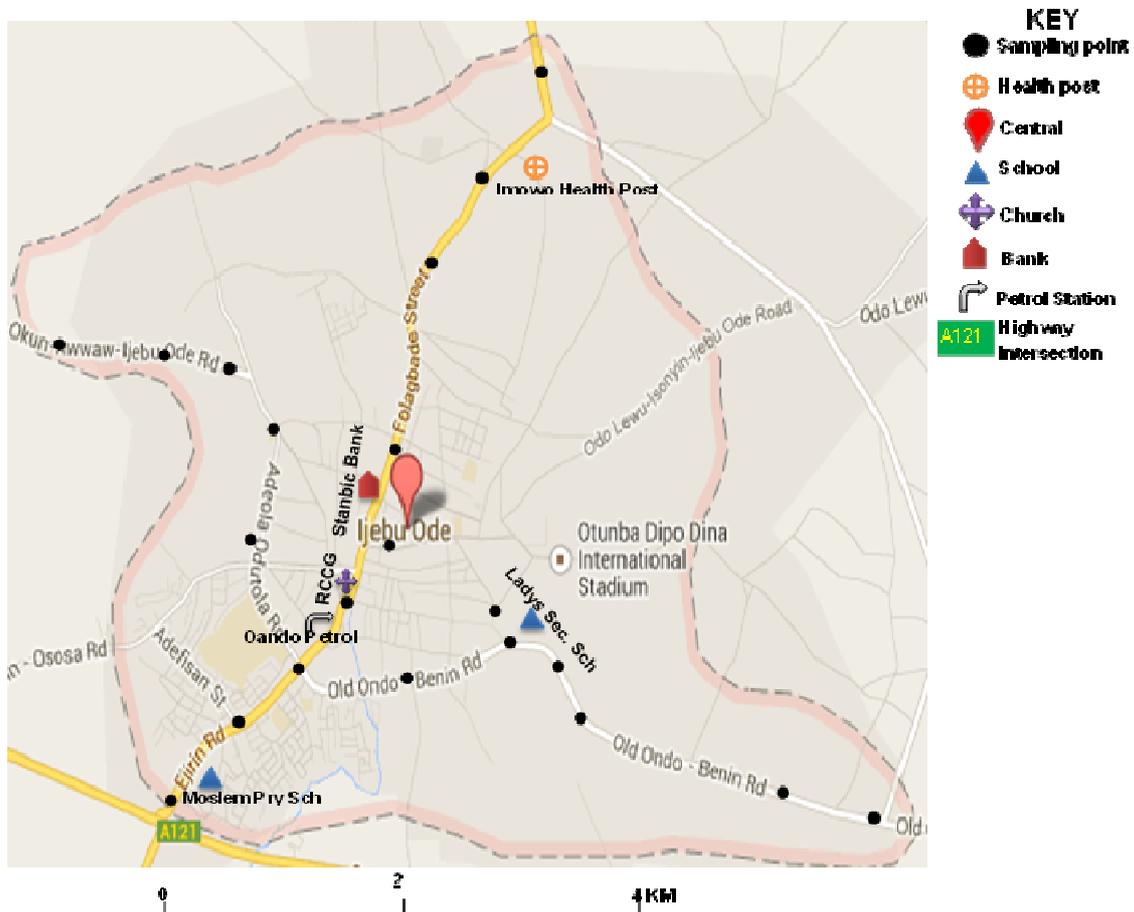
Figure 1: Ijebu-Ode Road networks showing the sampling point

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