MEASUREMENT OF NATURAL RADIOACTIVITY IN SOIL SAMPLES ALONG ROADWAYS IN HIGH COMMERCIAL AREAS OF THE KETU SOUTH DISTRICT OF THE VOLTA REGION, GHANA

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Abstract

Of recent, thoughts of awareness of radiological impact from soils on commuters along shoulders of roadways in commercial towns in Ghana have been conceived. Soils in such commercial areas can be contaminated with road dust to possibly alter their radiological exposures. They represent a potential source of environmental materials which can likely change the radiological exposure delivery of surface soils. In the present study, fifty surface soil samples were collected along six roadways in the Ketu South District (KSD) of the Volta Region, Ghana. The investigated area is a place of high commercial activities which make it experienced high traffic density comparatively. The samples were used to measure the specific activity concentration of ^{238}U, ^{232}Th and ^{40}K by means of HPGe gamma-ray spectrometry system. The results were further employed to evaluate the radiological health risks posed by the roadside soil. The activity concentration in the samples ranged from 103.25 to 123.13 Bqkg^{-1} for ^{238}U with an average of 112.39 Bqkg^{-1}. The activity concentrations of ^{232}Th range from 9.62 to 14.53 Bqkg^{-1} with an average of 11.73 Bqkg^{-1} whilst that of ^{40}K ranged from 53.21 to 140.85 Bqkg^{-1} with an average of 102.69 Bqkg^{-1}. These results were used in the estimation of the radiological hazard parameters in terms of radium equivalent activity (Ra_{eq}), external hazard index (H_{ex}), absorbed dose rate (D) and annual effective dose (E). The estimated values of these parameters were found less or lower than recommended or safe limits proposed by international bodies such as UNSEAR (2000) or ICRP (1991) indicating that the soil of the studied area is of normal natural background radiation. Thus, further indicating that roadside soils like others cannot be radiologically harmful to human health.

Introduction

The presence of primordial radionuclides in human habitats has always been a source of prolong exposure. Terrestrial radiation due to NORMs contributes a significant fraction to natural radiation exposure [1]. Natural radioactivity of soil, one of the main sources of exposure to humans, and the associated external exposure due to the gamma radiation depend primarily on the geological and geographical conditions of the region and appear at different levels in the soil of each region. Natural radionuclides in soil, rock and mineral include ^{238}U, ^{232}Th and ^{40}K. A significant part of the total dose contribution in the form of natural sources comes from terrestrial gamma radionuclides. They can cause a significant increase in exposure to workers or public and therefore cannot be disregarded from the radiation protection point of view.

Of recent, thoughts of likely awareness of radiological impact from soils on commuters along roadways in commercial towns in Ghana have been conceived. Exposure to natural sources of radiation is often influenced by human activities making the determination of the concentration of soil radioactivity an active matter of concern in providing a baseline data for ascertaining of their radiological levels [2]. Soils in such commercial areas can be contaminated with road dust to which can lead to changes in their natural radioactivity delivery. Road dust represents complex chemical composition and originates from the interaction of solid, liquid and gaseous materials produced from different sources and activities.

In the present study, surface soil samples were collected along six different roadways in the Ketu South District of the Volta Region, Ghana. The investigated area is an important district as it shares a boundary with the Republic of Togo. A place of high commercial activities which make it experienced high traffic density comparatively. The objectives of the study were to: collect soil samples along six important roadways in the KSD, measure the concentrations of natural radioactivity of the soil samples by virtue ^{238}U, ^{232}Th and ^{40}K; use the results to evaluate the health risks posed by natural radiation; compared the results of with similar international studies and also with some international recommendations; gather data as a baseline for the Volta Region of Ghana. Furthermore, observed whether the radiation levels of such soils are significantly than other soils principally used in buildings.

Materials and Methods

Study Area

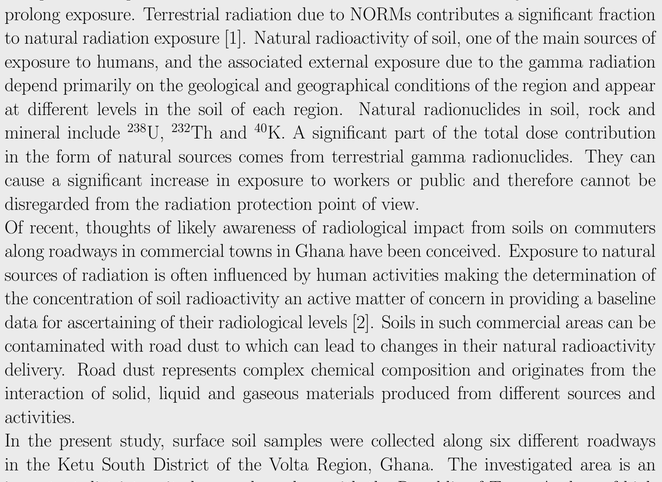

Fig. 1: Map showing the important roadways in the Ketu South District

Sample collection and analysis

A total of road deposited dust or street soil samples were collected along six main roads in the area. The roadways were selected on the basis of traffic load, population density and other anthropogenic activities. These roadways were Denu-Aflao road (DA); Market-District Hospital road (MH); Adafienu-Denu road (AD); Agbozome-Heglakope road (AH); and Heglakope-Ho road (HH). At every sampling location, dust composite samples were collected by sweeping not less than 5 cm from the surface using polyethylene hard brush and tray from four to six points of road edges during the dry season in March, 2017.

After removing visible impurities (stones, pebbles and organic matter), the soil samples were crushed in the laboratory, oven dried at a temperature of 105 ^{o}C for 8 h, and sieved through a 270 mesh. 100 g of the homogenous soil samples were then packed into marenelli beaker, weighed and carefully sealed and stored for at least 4 weeks before counting to allow time for ^{238}U and ^{232}Th to each reach equilibrium with their respective radionuclide daughters.

Radioactivity determination

Radioactivity concentration regarding ^{238}U, ^{232}Th and ^{40}K were determined by gamma-ray spectrometry system. The detailed of the method has been discussed by Sahoo [1]. The system was equipped with a high-resolution gamma ray spectrometry using HPGe detector Model GR 2518- 7500L (Canberra Industries Inc.) coupled to a computer based PCA-MR 8192 MCA mounted in a cylindrical 90 mm thick lead shield and an internal volume of approximately 99.53 L.

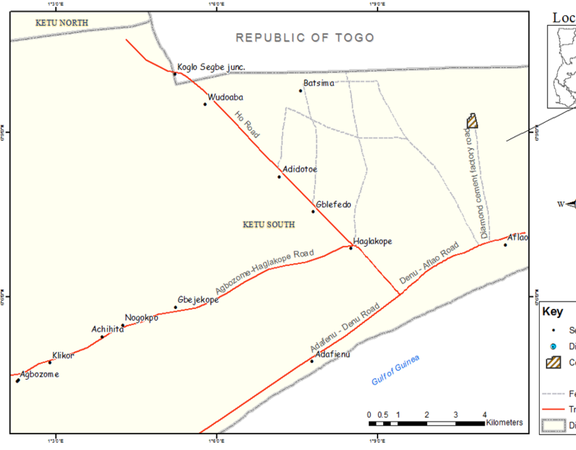

Fig. 2: Radioactivity measurement using HPGe detector

The radioactivity measurement of the samples was made by placing them on the detector inside the lead shielding and spectrum was collected for accumulation (Fig 2). The same geometry was used to determine peak area of samples and references. Each sample was measured during an accumulating time for 36,000s. The activity concentrations were calculated based on the weighted mean value of their respective decay products in equilibrium. The gamma-ray lines of 295.2 (18.2), 351.9 (35.1) keV from ^{214}Pb and the 609.3 (44.6), 1764.5 (15.1) keV from ^{214}Bi were used to determine the activity concentration of ^{226}Ra. The gamma lines of 338.4, the 911.2 (26.6) keV from ^{228}Ac, the 727.3 keV from ^{212}Bi and 583.2 (30.6) keV from ^{208}Tl were used to determine the activity concentration of ^{232}Th. The activity concentration of ^{40}K was measured directly by its own gamma ray at 1460.8 (10.7) keV. The values inside the parentheses following gamma-ray energy indicate the absolute emission probability of the gamma decay.

The gamma-ray background around the detector inside the shielding was determined using an empty container under identical measurement conditions.

This background was subtracted from the measured gamma-ray spectra of each sample before calculating the activity concentrations. The specific activity concentration, A_{Ei} of a radionuclide i and for a photopeak at energy E, is given by the analytical expression (Beck et al., 1972):

$$A_{Ei} = \frac{N_{Ei}}{\epsilon_{Ei} T_i \gamma_d M_s} \quad (1)$$

Where N_{Ei} is the net count for a sample at energy E, ϵ_{Ei} is the detector efficiency at energy E, T_c the counting live time, γ_d the gamma emission probability, and M_s the mass (dry weight) in kilogram of the sample.

Results

The results of the specific radioactivity values of ^{238}U (AU), ^{232}Th (ATh) and ^{40}K (AK) measured in the fifty roadside soil samples collected from six different roadways in the Ketu South District is presented in Table 1.

Table 1: Measured values and statistical summary of natural radionuclides of ^{238}U, ^{232}Th and ^{40}K in road soil samples along six roadways in the Ketu South District in the Volta Region

Roadways	Specific Activity Concentration (Bq/kg)		
	^{238}U	^{232}Th	^{40}K
(DC)	123.13	13.28	128.33
(DA)	104.61	12.47	140.85
(MH)	116.34	9.66	103.29
(AD)	116.09	9.62	112.21
(AH)	110.90	14.53	53.21
(HH)	103.25	10.79	78.25
Range	103.25 - 123.13	9.62 - 14.53	53.21 - 140.85
Mean	112.39	11.73	102.69
Median	113.50	11.63	107.75
Std. Dev.	7.63	2.02	32.40
World values	50	50	500

- From Table 1, It is clear that all the three radionuclides are present in the soils of each roadway in various concentrations, indicating that the soils may coming from similar geology.
- the percentage distribution of the radionuclides in soils of the study area are ^{238}U (49.6 %), ^{232}Th (5.17 %) and ^{40}K (45.3 %).
- Apart from 238U which is greater than world averages, the results obtained for 232Th and 40K were lower than the worldwide average concentrations of these radionuclides in soils reported by UNSCEAR [3], which are 50 Bq/kg for ^{238}U and ^{232}Th, and 370 Bq/kg for ^{40}K.
- The standard deviation values indicated that the concentration of 232Th is more evenly distributed in soils of the various roadways than the other radionuclides.

Calculation of the radiological hazard effects

To evaluate the radiological risk of exposure from the excess gamma radiation originating from the road side soils, some of radiological hazard indices were used and their estimation is captured in Table 2.

Table 2: Calculated values of Ra_{eq}, $I_{\gamma r}$,H_{in}, H_{ex}, D and E_o in the roadsoil samples of various roadways.

Roadways	Ra_{eq} (Bq/kg)	$I_{\gamma r}$ (Bq/kg)	H_{in} (Bq/kg)	H_{ex} (Bq/kg)	D (nGy/h)	E_o (mSv)
(DC)	152.002	1.039	0.744	0.411	70.259	0.086
(DA)	133.288	0.916	0.643	0.360	61.735	0.076
(MH)	138.107	0.941	0.688	0.373	63.891	0.078
(AD)	138.487	0.945	0.688	0.374	64.123	0.079
(AH)	135.775	0.920	0.667	0.367	62.231	0.076
(HH)	124.705	0.849	0.616	0.337	57.482	0.071
Mean	137.061	0.935	0.674	0.370	63.287	0.078
Recommended Safety limits	370.0	1.0	<1.0	<1.0	84.0	1.0

Radium equivalent activity (Ra_{eq})

To represent the activity levels of the radionuclides by a single quantity, which takes into account the radiation hazards associated with them, a common radiological index has been introduced called radium equivalent activity (Ra_{eq}) in Bq.kg, given by the expression [4]:

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (2)$$

- The equation is based on the estimation that 10 Bq/kg of ^{238}U (^{226}Ra) equal to 7 Bq/kg 0f ^{232}Th and 130 Bq/kg of ^{40}K to produce equal gamma-dose rate.
- From the Table 2, the Raeq values in the soil samples varies from 124.7 to 150.0 Bq/kg with a mean value of 137.1 Bq/kg and a standard deviation of 8.89. To keep the external dose < 1.5 Gy/h, the highest value of Raeq must be < 370 Bq/kg limit set by OECD [5]. All the soil samples Ra_{eq} values are less than the safe limits.
- In similar studies along roadways or urbanized environments, the results of the current study are comparable to those of Durusoy and Yildirim [6] in Rize Province, Turkey (127 Bq/kg) and Addo et al [7] in the Volta Region, Ghana (139 Bq/kg). However, the mean Raeq for the study is less than those obtained by Raghu et al [8] in Tiruvannamalai District, India (207 Bq/kg) and Manigandan and Shekar [9] W. Ghat, Iraq (208 Bq/kg), but greater than what was obtained by Al-Hamarneh [10] in Karak, South Jordan (101.3 Bq/kg) and Najam et al [11] in Ur City, Iraq (75.32 Bq/kg).
- All the above values were less than 370 Bq/kg safe limit set by UNSCEAR [2000].

Representative level index ($I_{\gamma r}$)

Another criterion $I_{\gamma r}$ is used to estimate the level of gamma radiation hazard associated with natural radioactivity in building materials and estimated by equation [5]:

$$I_{\gamma r} = A_{Ra}/150 + A_{Th}/100 + A_K/1500 \quad (3)$$

$I_{\gamma r}$ values were between 0.85 and 1.04, with a mean value of 0.94 (Table 2). It is noticed that $I_{\gamma r}$ average values were lower than unity ($I_{\gamma r} < 1$) which is the recommended safety value in about 83 % of the measured samples.

The External hazard Index (H_{ex}) and Internal hazard Index (H_{in})

A widely used radiological hazard parameters, the H_{ex} and H_{in} were used for the health hazard assessment. The H_{ex} is defined as follows [12]:

$$H_{ex} = A_U/370 + A_{Th}/259 + A_K/4810 \quad (4)$$

The calculated values H_{ex} (Table 2) for the soil samples were between 0.34 and 0.41 Bq/kg (mean:0.37 Bq/kg). Radioactivity may cause harm to the population if calculated values is higher than unity.

For the H_{in} is expressed by the following equation [12]:

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \quad (5)$$

The range of computed H_{in} for the road soil samples was between 0.616 Bq/kg and 0.744 Bq/kg with a mean value of 0.774 Bq/kg. Interestingly, 100 % of the samples are lower than unity, thus, fitting well with the universal assigned value showing that these soils are safe for any social use.

Absorbed Dose Rates (D) and Annual Effective Dose (E)

The absorbed dose rates (D) due to gamma radiations in air at 1 m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) were calculated based on guidelines provided by UNSCEAR 2000 [12]. The dose (D) was calculated from [12]:

$$D = 0.462A_{Ra} + 0.60A_{Th} + 0.417A_K \quad (6)$$

The average values of D for samples were 63.287 nGy/h. This value was lower than the world average value of 84 nGyh^{-1} sited by Turban and Gurbur [13].

For the general public who routinely used the shoulders of the roadways in the KSD, the annual effective dose (E_{ff}) was calculated in terms of outdoor occupancy factor situation only. The conversion factor (0.7SvGy^{-1}) and (0.2) for outdoor occupancy factors (Q) were used in the estimation of the E^{-1}. The formula for computing Eff is as follows [13]:

$$E_{eff} = D \times 8760(h/y) \times Q \times 0.7SvGy/h(conversionfactor) \times 10^{-6} \quad (7)$$

Where 8760 hy^{-1} is number of hours in one-year and 10^{-6} is the conversion factor between nano and milli.

The estimated range for the E_{ff} were between 0.071 and 0.086 mSv with a mean value of 0.078 mSv. These values were completely less than 1.0 mSv proposed by UNSCEAR [12] as the safety limit for the public.

CONCLUSION

The level and distribution of terrestrial natural radionuclides in samples of roadside soils from six roadways in the Ketu South District (KSD) have been determined using gamma-ray spectrometry system. From the results it was clear that with the exception of ^{238}U, ^{232}Th and ^{40}K were found to be normal according to international recommendations [3, 12].

The estimated results associated with the radiological health risk confirmed some facts which was in agreement with many similar worldwide reported values along roadways and urbanized environments. These results confirm, in general, that the radiological health parameters are lesser or within international recommended limits.

These facts imply anthropogenic activities which serves as sources of contamination for roadside soils like other soils do not over enhance their natural radioactivity. Therefore, this prompt a conclusion that soils of the various roadways within the KSD can be regarded as areas with normal background radiation. However, the current data prove to be informative and can be regarded as a baseline for similar studies in future for the Volta Region.

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