Assessment of Background Radiation In Playgrounds of Selected Basic Schools In The GA East Municipal District, Accra, Ghana

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Abstract

A study has been carried out in the playgrounds of selected basic schools in the Ga East municipal district of Accra, Ghana, to determine the exposure of school children to the radiation emitted by Naturally Occurring Radionuclide Materials and trace elements. The activity concentrations of different radionuclides were determined using high purity germanium (HPGe) detector. The average activity concentrations of ^{238}U, ^{232}Th and ^{40}K were found to be 19.8 ± 8.7, 29.1 ± 16.3 and $119.4 \pm 97.9\, Bq \cdot kg^{-1}$ respectively. The average annual effective dose calculated from these activity concentrations was $0.04\, mSv$ which is below the dose limit of $1\, mSv/year$ recommended by the International Commission on Radiological Protection (ICRP) for public exposure control. Radiological hazard assessments were carried out and the $Rn-222$ concentration and exhalation

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rate were estimated to be 32.13 $kBg \cdot m^{-3}$ and 0.016 $Bg \cdot m^{-2} \cdot s^{-1}$ respectively. These values are within the world average values..

Keywords: Accra, Natural radioactivity, Soil, Gamma spectroscopy, School playgrounds, Cancer, Ghana

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1 Introduction

Radionuclides are present everywhere in the environment where they emit gamma radiation (Aguko, 2013). The main natural contributors to gamma-radiation are the uranium and thorium series, together with potassium 40 (^{40}K) and they may be present in small quantities on the surface of the earth (Ajayi and Ibikunle, 2013; Darko and Faanu, 2008; Faanu et al., 2012). These naturally occurring radioactive materials (NORMs) are known to be the most significant means by which the public is exposed to ionizing radiation. However, in most countries including Ghana, the radiological hazards of the playgrounds of schools have not been investigated and as a result, the levels of exposure of students to ionizing radiation are unknown. This is particularly of concern where the ground of the school compound is bare and there is constant inhalation of dust. In the GA East municipal district of Accra, Ghana, there are over 31 basic schools and children spend time in playgrounds during school break time.

The Ga East Municipal District is located at 5;3;00N 0;12;00W and is bordered in the north by the Akuapim South District in the Eastern Region of Ghana. It is bordered on its other three sides by other districts in the Greater Accra Region of Ghana. On its west is the Ga West District, while on its south is the Accra Metropolis District and, in the east, is the Tema Metropolis District. The geology of the Ga East consists of Precambrian Dahomeyan schists, granodiorites, granites gneiss and amphibolites to late Precambrian Togo series comprising mainly quartzite, phillites, phylitones and quartz breccias. The soils in the metropolitan area can be divided into four main groups. These are the drift materials resulting from deposits by windblown erosion, alluvial and marine motted clays of comparatively recent origin derived from underlying shale which is the residual clays and gravels derived from weathered quartzites, gneiss and schist rocks, and lateritic sandy clay soils derived from weathered Accraian sandstone bedrock formations.

The towns in the Ga East district include Abokobi the capital, Dome and Taifa. There are also villages such as Ashongman, Haatso and Kwabenya in the district. Kwabenya is the location of the Ghana Atomic Energy Commission (GAEC).

The primary objective of this study was to determine the baseline radioactivity levels in playgrounds of selected basic schools in GA East municipal district of Accra, Ghana which would serve as reference data for monitoring of natural radionuclides levels in school playgrounds in Ghana especially the Ga East district. The study focused on the determination of radionuclide activity concentrations and dissemination of naturally occurring radionuclides of the U/Th decay series and ^{40}K in soil by gamma spectrometry.

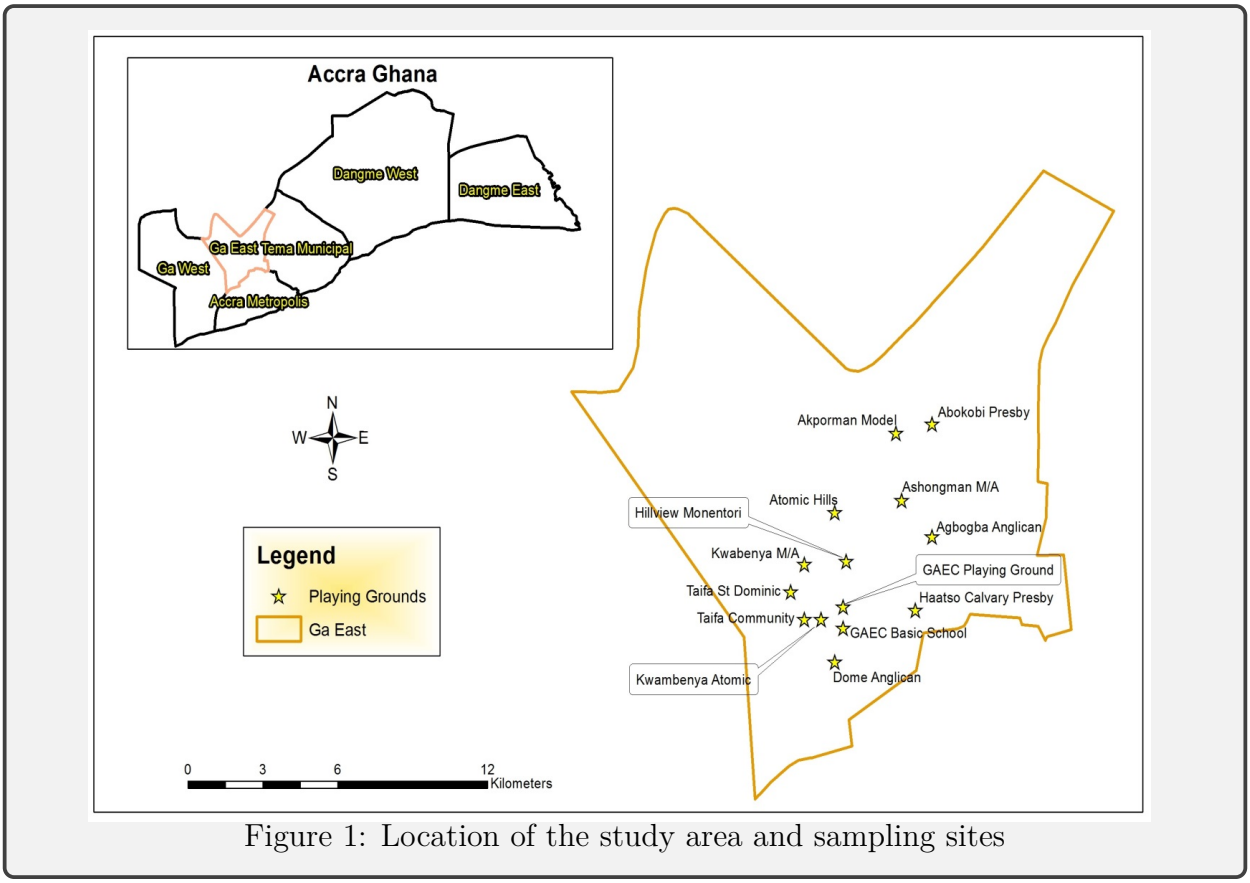

Figure 1: Location of the study area and sampling sites

2 Sampling and Sample Preparation

A total of 70 soil samples were collected from selected school playing grounds within Ga east district of greater Accra region during October/November 2014. Figure 1 shows the location of the sampling sites within the town of Ga East. For the soil samples, each playing ground of an area of $(64 \times 100)\, m^2$ was marked and 5 samples were randomly taken at depth up to 5 cm using a plastic dust pan and brush, and transferred into a clean polythene bag. The samples were properly labeled, catalogued and brought to the radiation laboratory at

the Radiation Protection Institute (RPI) at Ghana Atomic Energy Commission (GAEC). At each location, five measurements of the ambient gamma dose rates were taken at 1 m above the ground using a digital environmental radiation survey meter (RADOS, RDS-200 manufactured in Finland). The dose rate meter was calibrated at the Secondary Standard Dosimetry laboratory (SSDL) of RPI at GAEC. The average value was taken in $\mu Sv \cdot h^{-1}$. At the same time, the coordinates for each sampling location were recorded.

The five soil samples collected from a given playing ground were mixed together in the laboratory to obtain a composite sample that represents a particular school playing ground. The composite samples were air dried on trays for 7 days and then oven dried at a temperature of $105°C$ for between 3 and 4 hours, to remove all the moisture contents. Composite samples were grinded into fine powder (pulverized) using a ball mill to increase the total emission area (Faweya et al., 2014) and sieved through a 500 μm mesh size pore (so that clay and mineral particle may homogenize) and packed into 1 litre Marinelli beakers. The weight of each empty marinelli beaker as well as the weight of marinelli beaker with samples were measured using a mass balance in order to obtain the actual mass of soil samples $(0.01 - 2100\, g)$. The Marinelli beakers with the samples were then sealed and left for at least a month in order to allow secular equilibrium between ^{226}Ra and its decay products.

3 Instrumentation and Calibration

Direct instrumental without pre-treatment (non-destructive) was used for the measurement of gamma rays from the soil samples using a coaxial one open end, closed end and facing down HPGe detector (detector model GX4020, cryostat model 7500SL and preamplifier model 2002CSL). The detector has a diameter of 60.5 mm, length of 61.5 mm and distance from window (outside) of 6 mm. The resolution of the detector is 2.0 keV and the relative efficiency is 40% for 1.33 MeV gamma energy of ^{60}Co. The output of the detector was connected to PC. Identification of individual radionuclides was performed using their gamma ray energies, and the quantitative analysis of radionuclides was performed using gamma ray spectrum analysis software package, "Gennie 2000". The detector was surrounded by a lead shield (100 m) on all sides to reduce the background radiation level of the system, and lined inside with copper, cadmium and plexiglass (3 mm each) sheets to minimize the X-rays emitted due to interaction of cosmic radiation with lead.

The detector was cooled with liquid nitrogen at a temperature of $-196\,°C$ (77 k). In order to determine the background radiation in the environment around the detector, the empty Marinelli beakers were thoroughly cleaned and filled with distilled water and counted for $36,000\, s$ in the same geometry as the samples. The background spectra were used to correct the net peak area of gamma rays of measured isotopes. The background spectra were also

used to determine the minimum detectable activities of ^{238}U, ^{232}Th and ^{40}K of the detector.

The efficiency calibration of the detector was carried out by counting standard radionuclides manufactured by Czech metrology institute (Certificate number: 9031-OL-146/14, Type: MBSS 2, Product number: 050214-1425039,) which is a mixture of ^{241}Am, ^{109}Cd, ^{139}Ce, ^{57}Co, ^{60}Co, ^{137}Cs, ^{113}Sn, ^{85}Sr and ^{88}Y of known activities with well-defined energies in the energy range of 60 to 2000 keV. The standard was counted on the HPGe detector for 10 hours or 36000 s and the net counts for each of the full energy peaks in the spectrum was determined. These net counts and their corresponding energies were used to calculate the efficiency of the detector using the following expression (Darko et al., 2015).

$$Eff(E) = \frac{\text{Net Area}}{A_{std} \times P_{\gamma} \times T_{std}}, \tag{1}$$

where $Eff(E)$ is the efficiency of the detector, A_{std} is the activity (Bq) of the radionuclide in the calibration standard at the time of calibration, P_{γ} is gamma emission probability for energy (E) and T_{std} is the counting time of the standard.

4 Calculation of Activity Concentration and Estimation of Doses

The activity concentration (Bq/kg) of radionuclides in the samples were calculated using the relation (Darko et al., 2015).

$$A_{sp} = \frac{N_D \cdot e^{\lambda_P t_d}}{p \cdot T_c \cdot \eta(E) \cdot m}, \tag{2}$$

where N_D is the net count of the radionuclide in a sample, t_d is the delay time between sampling and counting, p is the gamma ray emission probability (gamma ray yield), $\eta(E)$ is the absolute counting efficiency of the detector system, T_c is the sample counting time, m is the mass of the sample (kg) or volume (l), $\exp(\lambda_P t_d)$ is the decay correction factor for delay between time of sampling and counting, and λ_p is the decay constant of the parent radionuclide. The measured specific activities of the radionuclides are in good agreement with the reference values. The activity concentration of ^{232}Th was determined by the mean of the specific activities of ^{208}Tl, ^{212}Pb and ^{228}Ac and the activity concentration of ^{226}Ra was the mean specific activity due to gamma energies of ^{214}Pb and ^{214}Bi. $K-40$ was measured directly using the 1460 KeV photo peak. Each sample was counted for 10 hours in order to reach $\pm 5\%$ of analytical accuracy of measurements.

A direct relationship between radioactivity concentrations of natural radionuclides and their exposure is referred to as absorbed dose rate in air at 1 m above the ground. This

was calculated from the activity concentrations using the following equation (Gbadago et al., 2011; Oyedele, 2006).

$$D_\gamma(nGyh^{-1}) = DCF_K \times A_K + DCF_U \times A_U + DCF_{Th} \times A_{Th}, \tag{3}$$

where $DCF_K = 0.0417$, $DCF_U = 0.462$ and $DCF_{Th} = 0.604$ are the absorbed dose rate conversion factors for ^{40}K, ^{238}U and ^{232}Th in $nGy \cdot h^{-1}/Bq \cdot kg^{-1}$ and A_K, A_U and A_{Th} are the activity concentrations for ^{40}K, ^{238}U and ^{232}Th respectively.

In order to estimate the radiological risk to which an individual is exposed, the absorbed dose is expressed in terms of annual effective dose equivalent from terrestrial gamma radiation taking into account the conversion coefficients from absorbed dose in air to effective dose which is estimated to be 0.7 Sv/Gy and the outdoor occupation factor of 0.2. Therefore, the outdoor annual effective dose equivalent was estimated by using the following equation (Oyedele and Shimboyo, 2013; Oyedele et al., 2008; Oyedele, 2013).

$$E_\gamma = D_\gamma \times 0.2 \times 8760 \times 0.7, \tag{4}$$

where E_γ is the average annual effective dose and D_γ is the absorbed dose rate in air.

The estimation of the concentration of radon in soil, C_{Rn}, in the absence of radon transport was made (using a proposal in UNSCEAR report) from the activity concentrations of ^{226}Ra using the equation (Faanu, 2011; UNSCEAR, 2000).

$$C_{Rn} = C_{Ra} \cdot f \cdot \rho_s \cdot \varepsilon^{-1}(1-\varepsilon)(m[k_T - 1] + 1)^{-1}, \tag{5}$$

where C_{Ra} is the activity concentration of ^{226}Ra in soil ($Bq \cdot kg^{-1}$), f is the radon emanation factor (0.2), ρ_s is the density of the soil grains ($2700\, kg \cdot m^{-3}$), is the total porosity (0.25), m is the fraction of the porosity that is water filled (0.95) (m is zero if the soil is dry) and k_T is the partition coefficient of radon between the water and air phases (0.23). Since in this study soil samples were dried before activity concentration measurements, therefore is zero. Thus the last term to one.

The major mechanism by which radon diffuses into the atmosphere is molecular diffusion. For a porous mass of homogeneous material, semi-infinite in extent, the flux density of radon at the surface of dry soil, J_D ($Bq \cdot m^{-2} \cdot s^{-1}$) is given by (UNSCEAR, 2000).

$$J_D = C_{Ra} \cdot \lambda_{Rn} \cdot f \cdot \rho_s(1-\varepsilon)L, \tag{6}$$

where C_{Ra} is the activity concentration of ^{226}Ra in earth material ($Bq \cdot kg^{-1}$), f is the emanation fraction for earth material (0.2), ρ_s is the soil grain density ($2700\, kg \cdot m^{-3}$), and ε is the porosity. λ_{Rn} and L are respectively the decay constant of ^{222}Rn ($2.1 \times 10\, s^{-1}$) and diffusion length (which is equal to $\left(\frac{D_e}{\lambda_{Rn}}\right)^{\frac{1}{2}}$ with $D_e = 2 \times 10^{-6}\, m^2 \cdot s^{-1}$).

5 Radiological Cancer Risk Assessment

The radiological fatality cancer risks and the severe hereditable effects due to exposure to NORMs were assessed for the playgrounds of basic schools. This was done by using the ICRP recommended risk assessment technique and the use of appropriate nominal probability coefficients for stochastic effects (ICRP, 2007). The ICRP recommended nominal risk coefficients for stochastic effects are shown in Table 1 (ICRP, 2007). The risk to fatality cancer and hereditary effect were estimated as follow:

Fatality cancer risk = Annual effective dose (Sv) cancer nominal risk factor
Hereditary effects risk = Annual effective dose (Sv) hereditary nominal risk factor.

Table 1: Detriment adjusted nominal risk coefficients for stochastic effects after exposure to radiation at low dose rate (ICRP, 2007).

Exposed population	Cancer fatality		Heritable effects		Total	
ICRP publication	103	60	103	60	103	60
Whole	5.5	6	0.2	1.3	5.7	7.3
Adults	4.1	4.8	0.1	0.8	4.2	5.6

Note: Use detriment-adjusted nominal risk coefficients ($1E-02Sv^{-1}$) for stochastic effects after exposure to radiation at low dose rate.

6 Results and Discussion

Figure 1 shows the map of Accra and locations where sampling was carried out within the Ga East municipal assembly of Greater Accra. Table 2 shows the absorbed dose rate measured in air at $1\,m$ above the ground at the sampling points. The table indicates the range and average values of the absorbed dose as well as the calculated annual effective doses. The measured absorbed dose rates varied in a range of $60-140\,nGyh^{-1}$ with an average value of $82.0\pm6.5\,nGyh^{-1}$. The corresponding average annual effective dose was calculated to be $101\pm11\mu Sv$ $(0.101\pm0.011mSv)$ in a range of $81-115\,\mu Sv$ $(0.081-0.115mSv)$. The results of the absorbed dose rates in this study compare well with the range of dose rates reported for other countries (UNSCEAR, 2000). The highest absorbed dose rate value of $140\,nGyh^{-1}$ was measured at Dome Anglican. The high absorbed dose rate in this area could be attributed to cosmic radiation and natural abundance of radionuclides in the soil of the area. The average activity concentration of ^{238}U is $19.8\pm8.7\,Bqkg^{-1}$ in a range of $9.7-40.3\,Bqkg^{-1}$ as shown in Table 3. The average activity concentration of ^{232}Th is $29.1\pm16.3\,Bqkg^{-1}$ in a range of $9.2-66.4\,Bqkg^{-1}$ and the average activity concentration of

^{40}K is 119.4 ± 97.9 in a range of $20.4 - 342.2$ as shown in Table 3. Figure 2 shows graphically the activity concentrations of radionuclides from different sampling locations. The worldwide average activity concentrations of ^{238}U, ^{232}Th and ^{40}K in soil samples are 35, 30 and 400, respectively (UNSCEAR, 2000).

Table 2: Average absorbed dose rate in air at 1 m above the sampling points and the calculated annual effective dose.

Sampling location	Description	Absorbed dose rate ($nGyh^{-1}$)		Annual effective dose (mSv)
		Range	Average $\pm\sigma$	
AP	Abokobi Presby	60-110	86 ± 18	0.105
AG	Agbogba Anglican	80-100	94 ± 13	0.115
AP	Akporman Model	60-90	74 ± 13	0.091
AS	Ashongman M/A	60-100	80 ± 20	0.098
AH	Atomic Hills	60-90	74 ± 15	0.091
DA	Dome Anglican	60-140	92 ± 30	0.113
GS	GAEC Basic School	60-100	76 ± 17	0.093
GP	GAEC Playing Ground	60-100	78 ± 18	0.096
HC	Haatso Calvary Presby	60-100	80 ± 20	0.098
HM	Hillview Montessori	60-100	74 ± 17	0.091
KA	Kwabenya Atomic M/A	60-130	96 ± 29	0.118
KW	Kwabenya M/A	60-110	90 ± 23	0.11
TC	Taifa Community	60-130	88 ± 29	0.108
TD	Taifa St Dominic	60-80	66 ± 9	0.081
Average $\pm\sigma$			82.0 ± 6.5	0.101 ± 0.011

A comparison of the average activity concentrations observed in this study with the corresponding world average activity concentrations shows that the average concentration of, ^{238}U is about half that of the world average value while the concentration of ^{232}Th is nearly the same as that of the world average, and the average activity concentration of ^{40}K is only about one-quarter of the world average value (UNSCEAR, 2000). It therefore follows that the average activity concentrations obtained in this study are lower than those of the corresponding world average activity concentrations. Also, the average activity concentrations obtained in this study are far below the exemption values of 1000 $Bqkg^{-1}$ for ^{238}U and ^{232}Th, and 10000 $Bqkg^{-1}$ for ^{40}K in material that will warrant regulatory control (IAEA, 2011).

The average gamma dose rate and annual effective dose from terrestrial gamma rays calculated from the activity concentrations are shown in Table 3 (columns 5 and 6). The average absorbed dose rate is found to be $31.7 \pm 17.4\ nGyh^{-1}$ (in a range of $11.3 - 73.0\ nGyh^{-1}$), which is about two and a half times smaller than the dose rate (82.0 ± 6.5) measured in air at $1\ m$ above the ground (Table 2). This difference is attributed to the contribution of cosmic radiation toward terrestrial environment. Figure 3 shows graphically the calculated absorbed dose rates in air for the different playgrounds. It was observed that absorbed dose is greater in Agbogba Anglican with and lowest in Atomic Hills with . The average absorbed dose rate due to the activity concentrations ($31.7\ nGyh^{-1}$) is about half of the worldwide average

Table 3: Activity concentrations in soil samples of different playgrounds

Sample location	Activity concentration (Bq/kg)			Absorbed Dose rate ($nGyh^{-1}$)	Annual Effective dose (nSv)
	^{238}U	^{232}Th	^{40}K		
Abokobi Presby	21.9 ± 1.5	37.9 ± 1.4	63.7 ± 6.8	35.7	0.044
Agbogba Anglican	40.3 ± 3.1	66.4 ± 1.5	342.2 ± 35.6	73.0	0.09
Akporman Model	16.1 ± 0.5	23.2 ± 1.0	85.2 ± 9.0	25.0	0.031
Ashongman M/A	26.9 ± 1.5	41.6 ± 3.2	269.1 ± 28.1	48.8	0.06
Atomic Hills	10.5 ± 0.5	9.2 ± 1.7	20.4 ± 2.3	11.3	0.014
Dome Anglican	25.5 ± 1.4	23.9 ± 4.1	142.0 ± 14.8	32.2	0.039
GAEC Basic School	23.2 ± 1.3	32.1 ± 0.3	67.8 ± 7.2	32.9	0.04
GAEC Playing Groung	17.4 ± 1.3	28.8 ± 0.6	103.5 ± 10.9	29.8	0.037
Haatso Calvary Presby	23.5 ± 1.1	40.9 ± 2.5	219.5 ± 22.9	44.7	0.055
Hillview Montessori	11.5 ± 0.6	14.8 ± 1.4	24.4 ± 2.7	15.3	0.019
Kwabenya Atomic M/A	27.2 ± 1.2	45.8 ± 2.1	170.1 ± 17.8	47.3	0.058
Kwabenya M/A	9.7 ± 1.5	9.5 ± 1.9	47.9 ± 5.1	12.3	0.015
Taifa Community	10.2 ± 0.6	12.3 ± 2.4	78.4 ± 8.3	15.4	0.019
Taifa St Dominic	13.7 ± 0.4	2.06 ± 1.5	37.3 ± 4.0	20.3	0.025
Average	19.8	29.1	119.4	31.7	0.039
Standard deviation	8.7	16.3	97.9	17.4	0.021
Range	9.7-4.03	9.2-66.4	20.4-342.2	11.3-73.0	0.014-0.090
World average	35	30	400		

value of $60\, nGyh^{-1}$ (UNSCEAR, 2000). This difference could be attributed to differences in the geology and geochemical state of the sampling sites. The corresponding average annual effective dose estimated from the activity concentrations is $0.039 \pm 0.021\, mSv$ in a range of $0.014 - 0.090\, mSv$ as shown in Table 3 (column 5). Figure 4 shows graphical interpratation where Agboba Anglican receives a greatest annual effecetive dose of $0.090\, mSv$ and Atomic Hills receives the least annual effective dose of $0.014\, mSv$.

A comparison of the results of the annual effective dose from the two different exposure pathways is shown in Figure 5. The higher annual effective dose is observed from the abient measurement of direct gamma ray at $1\, m$ above the ground. This is because of the contribution of cosmogenic radionuclides from the sun and from sources within and beyond the galaxy in addition to terrestrial radionuclides.

The activity concentrations of Radon-222 in the soil matrix were calculated from the activity concentrations of ^{226}Ra in the soil samples. The results obtained are shown in Table 4. The mean activity concentration of ^{222}Rn in the soil was $32.13\, kBq \cdot m^{-3}$ in a range of $15.79 - 65.36\, kBq \cdot m^{-3}$ which are below the world average value of $78\, kBq \cdot m^{-3}$ reported by UNSCEAR (2000). The mean exhalation rate was 0.016 (in a range of 0.008 - 0.033) and this compares well with the world average value of $0.033\, Bq \cdot m^{-2} \cdot s^{-1}$ reported by UNSCEAR (2000).

Table 5 shows the estimated radiological fatality cancer risk and severe hereditary effect

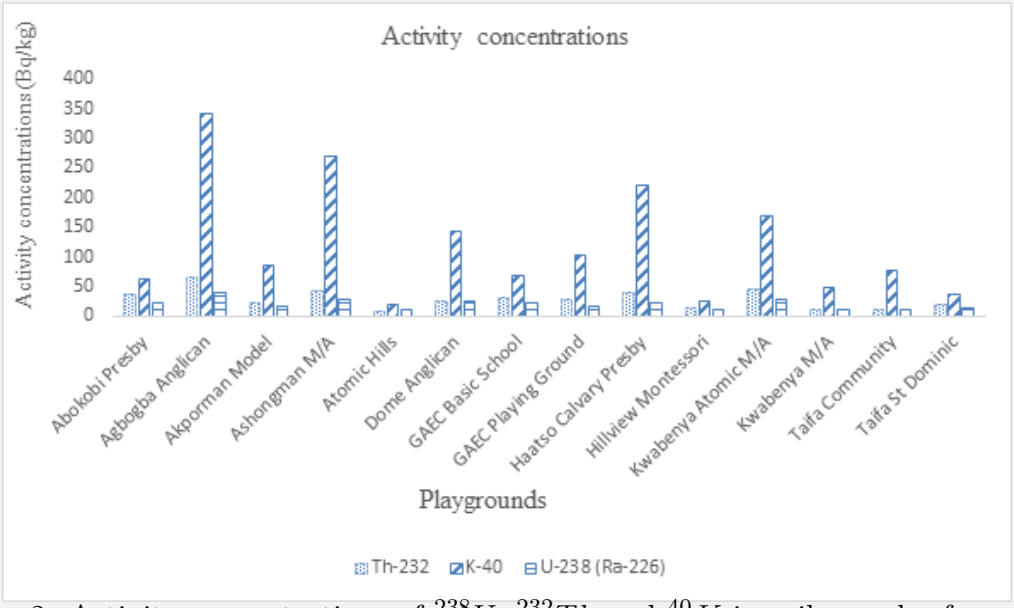

Figure 2: Activity concentrations of ^{238}U, ^{232}Th and ^{40}K in soil samples from study areas.

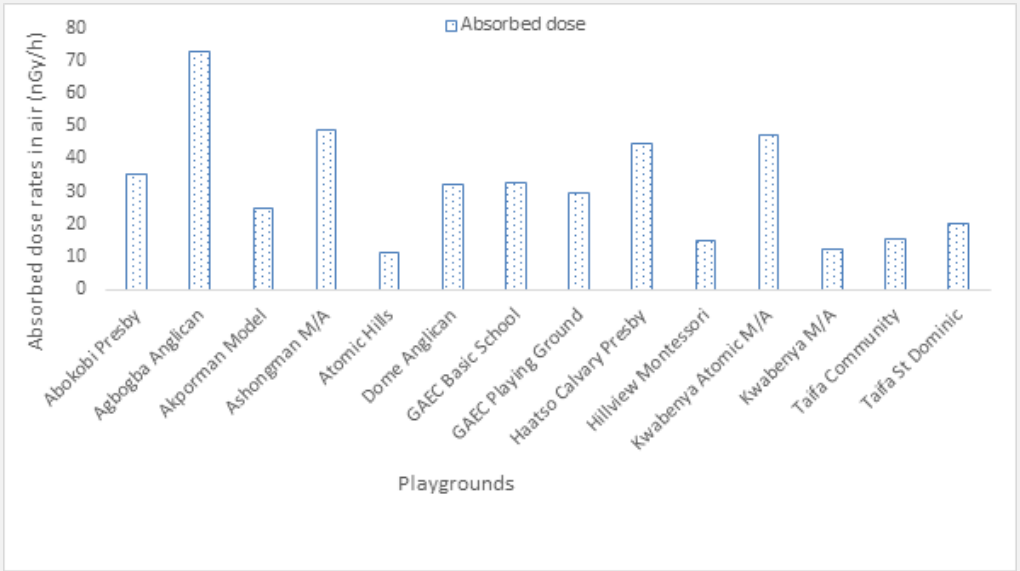

Figure 3: Comparison of Absorbed dose rates in different playing grounds.

to the public at each of the playground. The risk of exposure to low doses and dose rates of radiation was estimated using the 2007 recommended risk coefficients and an assumed 70 years lifetime of continuous exposure of the population to low level radiation (ICRP, 2007).

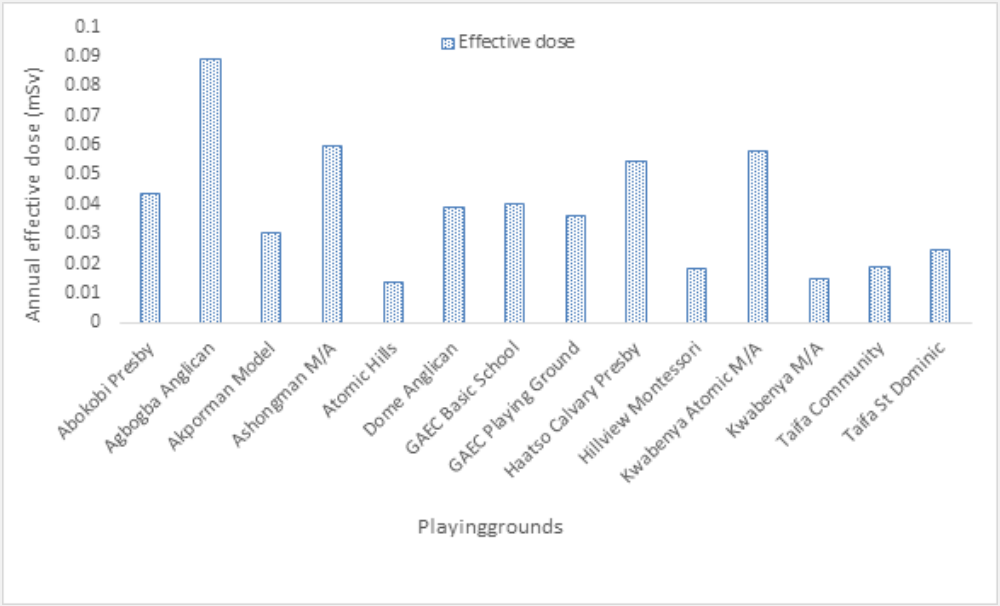

Figure 4: Comparison of annual effective dose in different playing grounds.

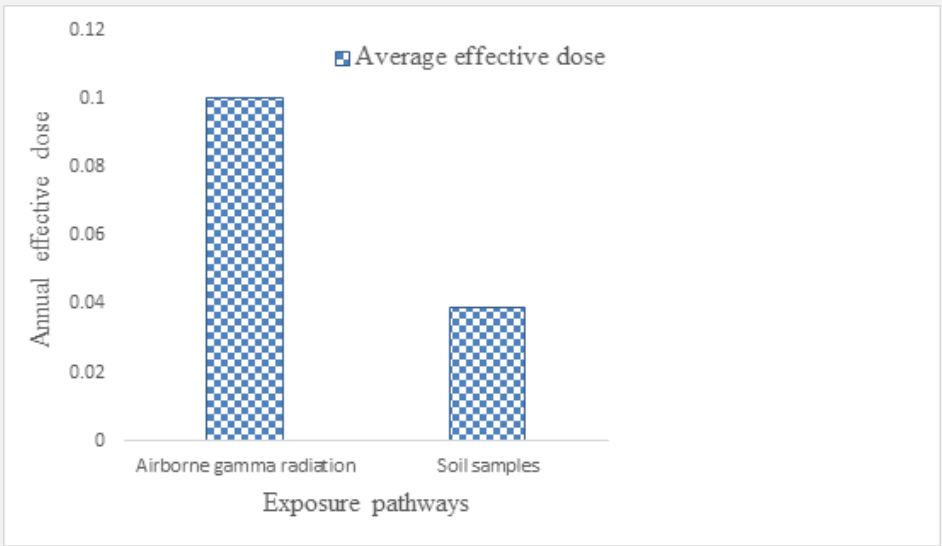

Figure 5: Comparison of Annual effective doses from different exposure pathways of radiation.

The average fatality cancer risks for all playgrounds were in a range of $7.62 \times 10^{-7} - 4.92 \times 10^{-7}$ with the average of 2.14×10^{-6}. This suggests that approximately 2 persons out of a 1 000 000 people are likely to suffer from cancer as a result of external irradiation from the soil or playground, and this is considered to be insignificant. The lifetime fatality cancer

Table 4: Estimated concentrations of ^{222}Rn in the soil and their corresponding exhalation rate

Sample location	Description	$C_{Ra}(Bq \cdot kg^{-1})$	$C_{Rn}(kBq \cdot m^{-3})$	E_x rate$(Bq \cdot m^{-2} \cdot s^{-1})$
AP	Abokobi Presby	21.89	35.46	0.018
AG	Agbogba Anglican	40.35	65.36	0.033
AP	Akporman Model	16.08	26.04	0.013
AS	Ashongman M/A	26.86	43.52	0.022
AH	Atomic Hills	10.55	17.09	0.009
DA	Dome Anglican	25.52	41.35	0.021
GS	GAEC Basic School	23.15	37.51	0.019
GP	GAEC Playing Ground	17.38	28.16	0.014
HC	Haatso Calvary Presby	23.48	38.03	0.019
HM	Hillview Montessori	11.52	18.67	0.010
KA	Kwabenya Atomic M/A	27.20	44.06	0.023
KW	Kwabenya M/A	9.75	15.79	0.008
TC	Taifa Community	10.18	16.50	0.008
TD	Taifa St Dominic	13.74	22.27	0.011
Mean		19.83	32.13	0.016
St. Dev		8.74	32.13	0.007
Min		9.75	15.79	0.008
Max		40.35	65.36	0.033

Table 5: Estimated cancer risk components for external irradiation of ^{238}U, ^{232}Th and ^{40}K in different playgrounds.

Sample location	Annual effective dose (Sv) 10^{-5}	Fatality cancer risk to population per year 10^{-6}	Life time fatality cancer risk to population 10^{-4}	Severe hereditary effects per year 10^{-7}	Estimated lifetime hereditary effects 10^{-6}
Abokobi Presby	4.38	2.41	1.68	0.88	6.13
Agbogba Anglican	8.95	4.92	3.45	1.79	12.5
Akporman Model	3.07	1.69	1.18	0.61	4.29
Ashongman M/A	5.98	3.29	2.30	1.20	8.37
Atomic Hills	1.38	0.76	0.53	0.27	1.94
Dome Anglican	3.94	2.17	1.52	0.79	5.52
GAEC Basic School	4.04	2.22	1.55	0.81	5.56
GAEC Playing Ground	3.65	2.01	1.41	0.73	5.11
Haatso Calvary Presby	5.48	3.01	2.11	1.10	7.67
Hillview Montessori	1.87	1.03	7.20	0.37	2.62
Kwabenya Atomic M/A	5.81	3.19	2.24	1.16	8.13
Kwabenya M/A	1.50	0.83	0.58	0.31	2.10
Taifa Community	1.89	1.04	7.26	0.38	2.64
Taifa St Dominic	2.49	1.37	0.96	0.50	3.49
Average	3.89	2.14	1.50	0.78	5.44
Standard Deviation	2.13	1.17	0.82	0.43	2.99
Min	1.38	0.76	0.53	0.28	1.94
Max	8.95	4.92	3.45	1.79	12.5

risk for all were in a range of 5.33×10^{-5} to 3.45×10^{-4} with an average of 1.50×10^{-4} which suggests that approximately 1 person out of a 10 000 is likely to suffer from cancer. On the other hand, severe hereditary effects per year and estimated lifetime hereditary effects were in a range of 2.77×10^{-8} to 1.79×10^{-7} and 1.94×10^{-6} to 1.25×10^{-5} with averages of 7.78×10^{-8} and 5.44×10^{-6} respectively. These average values indicate that approximately none out of 100 000 000 people is likely to suffer from hereditary diseases per year and approximately 5 persons out of 100 000 are likely to suffer from hereditary related diseases due to low background radiation exposure. The average lifetime fatality cancer risk for the population in the study area is 1.50×10^{-4} which is within the United States Environmental Protection Agency (USEPA) acceptable range of risks 1×10^{-6} to 1×10^{-4} (Faanu et al., 2012; USEPA, 1993). However a risk value of 1×10^{-6}, that is 1 case out of a million people dying from cancer, is considered as trivial.

7 Conclusions

The study considered the evaluation of Naturally Occurring Radionuclides Materials (NORMs) in the playgrounds of basic schools in Ga East District. Also, the radiological fatality cancer risk and severe hereditary effect assessments were carried out. The mean activity concentrations of ^{238}U, ^{232}Th and ^{40}K, were found to be 19.8 ± 8.7, 29.1 ± 16.3 and $119.4 \pm 97.9\ Bq \cdot kg^{-1}$ respectively. These results are below the worldwide average activity concentrations (UNSCEAR, 2000). The mean annual effective doses estimated from direct external gamma ray exposure from natural radioactivity concentrations in soil is estimated to be $0.039\ mSv/year$ which is lower than the $1\ mSv/year$ dose limit recommended by the ICRP for public radiation exposure control (ICRP, 2007) and this indicates that there is no significant radiological hazard to the public. The results obtained from cancer risk assessment performed according to ICRP method shows no significant hazard to the public. The activity concentration of ^{222}Rn in soil in the absence of transportation, and the exhalation rate were calculated and they compare well with the world average values suggested by United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2000).

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