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Assessment of Natural Radioactive Materials in Building Materials Used along the Coast of Central Region of Ghana

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Abstract: The naturally occurring radioactive materials associate with building materials from twelve (12) towns along coastal part of Central Region of Ghana have been studied. The activity concentration of ^{238}U, ^{232}Th and ^{40}K ranged from 27.90±1.06 to 97.89±6.34 Bq/kg, 15.47±0.97 to 70.97±5.83 Bq/kg and 89.34±5.20 to 943.44±34 Bq/kg, respectively. The ^{238}U recorded the highest value of 97.89±6.34 Bq/kg in granite from Ampenyi whilst pebbles from Winneba recorded the lowest activity concentration. The ^{232}Th activity concentration level ranged from 15.47±0.97 to 70.97±5.83 Bq/kg with clay soil from Kormantse recording the highest whiles pebbles from Apam had the lowest average activity concentration. The average activity concentration of ^{40}K ranged from 89.34±5.20 to 943.44±34 Bq/kg , with the highest activity concentration level occurring in Ampenyi and lowest level of the activity concentration also occurring in beach sand from Apam. The activities are compared with available data from other publications and with the world average value for soils. The radium equivalent activity Ra_{eq}, the external hazard index (H_{ex}) (0.17 to 0.48), Internal hazard index (H_{in}) (0.25 to 0.72), the absorbed dose rate D in air (36.90 to 131.29 nGy/h) and the annual effective dose (E_T) (181.02 to 644.00 μSv/yr) were evaluated to assess the radiation hazard for people living in dwellings made of these building materials. The studies indicated that the main contributions to gamma–radiation in building materials are ^{40}K, ^{238}U and ^{232}Th. The results obtained were found to be within the allowable limit of 1mSv per year for public exposure control recommended by the International Commission Radiological Protection (ICRP) and Organization for Economic Cooperation and Development (OECD).

Key words: Building materials, effective dose, external and Internal hazard indexes, NORMS, gamma spectrometry, radium equivalent

INTRODUCTION

Naturally occurring radioactive materials (NORMS) are acknowledged as the largest sources of exposure to human health (UNSCEAR, 1993, 2000). It is also established that ionizing radiation may cause damage to human tissues and other biological systems (Arafa, 2004; Darko *et al*., 2005). The building materials and their processed products contain radionuclides of the two most commonly known radioactive series namely, the uranium and thorium series as well as potassium-40 (Amrani and Tahtat, 2001; Ngachin *et al*., 2007; Swedjemark, 1977). In recent times, attention has been paid to artificial radionuclides than radionuclides of natural origin, though it is known that the contribution of artificial radionuclides in our environment is much smaller (UNSCEAR, 2000). Natural radionuclides in building materials namely soil, sandcrete block, concrete block and granite generate significant component of background radiation exposure of the global population.

Radiation exposure due to the building materials can be divided into external and internal exposures. The external exposure is caused by direct gamma radiation whereas the internal exposure is caused by the inhalation of radioactive inert gas radon (^{222}Rn, a daughter product of ^{238}U) and its short-lived secondary decay products. In order to assess the radiological hazards to human health, it is important to study the radioactivity levels emitted by the building materials (Leung *et al*., 1998).

The radiations which humans are exposed to may increase if they live in houses or buildings constructed using materials whose radiation doses are above normal background radiation level in the area (Cliff *et al*., 1985). The radiological implications of living or working in buildings made from these building materials is the increase in external exposure of the body due to

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gamma - emitting radionuclides (Beretka *et al*., 1985; Dainius and Aloyzas, 2007).

A number of studies on radioactivity in building materials have been carried out in many different countries around the world for the purpose of estimating the population exposure to natural background radiation. (Al-Jarallah *et al*., 2001; Arafa, 2004; El-Dine *et al*., 2001; Giuseppe *et al*., 1996; Hussain *et al*., 2010; Kovler *et al*., 2002; Malanca *et al*., 1993; Muhammad *et al*., 2001; Ngachin *et al*., 2007; Petropoulos *et al*., 2002; Sroor *et al*., 2001; Stoulos *et al*., 2003; Tzortzis *et al*., 2003; UNSCEAR, 1988). In Ghana there are a few comparable studies in building materials (Andam, 1994). Most studies carried out have concentrated on radioactivity in soils and rocks (Andam, 1994; Darko *et al*., 2005; Yeboah *et al*., 2001). Knowledge of the activity of naturally occurring radioactive materials (NORMS) is very important due to the fact that it constitutes the largest source of population exposure, and its assessment will lead to setting up of radiation protection exposure level.

Results from the study will provide useful data and information on radioactivity levels in building materials and aid in decision-making processes in setting up guidelines for the control of radiation exposure in dwellings in Ghana. It will also engender interest for further research into NORMS in all types of building materials from all the geographical regions of the country.

EXPERIMENTAL METHOD

Sample collection and preparation: The samples were collected from coastal areas of Central Region of Ghana between the periods of January to June and brought to the Environmental Laboratory of Radiation Protection Institute, Ghana Atomic Energy Commission to conduct the experimental work.

The building materials collected from the coastal communities and towns for this study include granite, clay soil, sandcrete, sandy soil, beach sand, and pebbles. Samples with large grain size were crushed, ground, homogenized, air-dried and sieved to a umiform mixture to particle size of about 5 μm, sealed in 1.0 L Marinelli beaker and stored at room temperature for period of 3-4 weeks to allow ^{238}U and ^{232}Th decay series to reach radioactive equilibrium with it short live progeny (Amrani and Tahtat, 2001; Khan *et al*., 1992, 2002; Kumar *et al*., 2003).

Gamma spectrometric measurements:

Gamma spectrometry: The gamma spectrometer used for this work consists of a detector, preamplifier and detector bias supply, pulse-height analyzer, data readout capability, and shielded sample enclosure. The detector is made up of a high purity germanium (HPGe) detector coupled to a multichannel analyser (MCA) with software for data acquisition. The logic control capabilities allow data storage in various modes and display or recall of data.

The detector crystal has a diameter of about 36 mm and thickness of about 10 mm. The crystal is housed in an aluminium canister with a 0.5 mm thick beryllium entrance window. A lead shield, built with 5 cm thick lead bricks surrounds the detector to prevent it from external radiation reaching the detector. The detector is coupled to a Canberra 1510 signal processing unit which contains the power supply, amplifier and analog to digital converter. Digitized counts are collected in a Canberra S100 multichannel analyzer. Spectrum acquisition and analysis are performed with APTEC software. The Germanium detector is connected to an Uninterrupted Power Supply (UPS). The ambient temperature around the detector was relatively fluctuated between 16 and 27ºC during the period of measurement and detector was then cooled down to about 77 K by liquid N_2.

Calibration of the gamma spectrometry and activity concentration: The detector and measuring assembly was calibrated for energy and efficiency in order to determine the type of radionuclides and the quantities present. The calibrations were done manually using a 1.0 L Marinelli beaker with mixed radionuclide standard solution supplied by the IAEA. The standard solution contains the following radionuclides with corresponding energies ^{241}Am (60 keV), ^{109}Cd (88 keV), ^{57}Co (122 keV), ^{139}Ce (1656 keV), ^{203}Hg (279 keV), ^{113}Sn (391.69 keV), ^{85}Sr (514 keV), ^{137}Cs (662 keV), ^{88}Yt (898 keV and 1836 keV) and ^{60}Co (1173 keV and 1333 keV).

The samples were counted for 36,000 s. Background measurements were also made for the same period and subtracted from the samples (Darko *et al*., 2005; Yeboah *et al*., 2001) with the high resolution gamma ray spectrometer made up of high purity germanium (HPGE) detector and counting assembly. The Canberra S100 MCA and APTEC software programme were used for spectrum acquisition and analysis. The weight of each sample, sampling date and time, counting date and time were recorded.

The activity concentration (Bq/kg) in each of the sample in the spectrum was calculated using the analytical expression (Beck *et al*., 1972):

$$A_C = \frac{N_{sam}}{P(E) * \eta(E) * T_C * M_{sam}} \qquad (1)$$

where, M_{sam} (kg) is the mass of sample, N_{sam} (cps) is the net peak area for the sample in peak range, P(E) is the gamma emission probability, T_C is the counting time in seconds, η(E) is the photopeak efficiency.

The activity concentrations of the parent nuclides were obtained using their daughter nuclide activity concentrations assumption of attainment of secular equilibrium within the period of storage. The transition lines (609.34, 1764.51 keV) of ^{214}Bi and (583.32, 2614.56 keV) of ^{208}TI were used to determine the activity concentration of ^{238}U and ^{232}Th, respectively. ^{40}K was determined directly with its only 1460.75 keV peak transition line.

RESULTS AND DISCUSSION

Activity concentration: In this study forty-six (46) samples from twelve (12) different towns along coastal part of central region of Ghana were investigated. The building materials were measured for natural radionuclides such as ^{238}U, ^{232}Th and ^{40}K. The activities concentrations were calculated according to UNSCEAR (2000) report. The Table 1 shows activity concentration of each radionuclide in the measured sample together with their corresponding uncertainties. The average activity concentration of ^{40}K ranged from 89.34±5.20 Bq/kg in the beach sand from Apam to 943.44±34 Bq/kg of granite from Ampenyi. The average activity concentration of ^{238}U vary from 27.90±1.06 to 97.89±6.34 Bq/kg with granite from Ampenyi measured the highest activity while pebbles from Winneba recorded the lowest activity concentration. The average activities concentration of ^{232}Th range from 15.47±0.97 to 70.97±5.83 Bq/kg with clay soil from Kormantse recorded the highest while pebbles of Apam had the lowest average activity concentration. The granite samples from all the locations in the central region and clay soil from Kasoa and Komenda recorded a value exceeding the worldwide average activity concentration with other building materials shown relative radioactivity level lower than world average value of 370 Bq/kg (Bou-Rabee and Bem, 1996). The average activity concentration of ^{40}K from granite in Kasoa, Saltpond, Biriwa, Ampenyi and Komenda measured activity concentration greater than twice of the average worldwide soil activity concentration. The ^{238}U content in all building materials investigated measured activity concentration greater than that of average worldwide of (25 Bq/kg). The average activity concentration of granite from Kasoa, Apam, Saltpond, Kormantse, Ampenyi and clay from Kasoa were more than 3 times the worldwide average activities concentration of ^{238}U of soil with exception of Komenda which recorded average activities far greater than 4times the worldwide average activity concentration.

The average activity concentrations of ^{232}Th in building materials investigated were more than the worldwide average activity concentration with exception of pebbles from Apam and beach sand from Komenda, whiles clay soil from Kormantse measured activity concentration twice greater than worldwide average activity concentration of soil (25 Bq/kg). The most significant radionuclide identified was ^{40}K. The ^{40}K content in all the building materials was higher than those of other radionuclide. The results also indicate that the main contributions to gamma-radiation in the building materials are ^{238}U, ^{232}Th and ^{40}K. Due to the different composition of building materials and uneven distribution of the radionuclides in the samples, the quantities of natural radionuclides are also found to be different (Kathren, 1998). The variation in the figures observed in the different location is a function of the local geology and could be attributed to the physical and chemical sorting of the materials from location to location.

Calculation of radiation hazards:

Radium equivalent activity: The ^{226}Ra, ^{232}Th and ^{40}K are not uniformly distributed in building materials. In order to determine the specific activity of each building materials, the radium equivalent activity calculated using the expression (Beretka and Mathew, 1985; Hayambu *et al*., 1995; Tufai *et al*., 1992):

$$Ra_{eq} = A_C\,(Ra\,) + 1.43 * A_C\,(Th) + 0.077 * A_C\,(K) \quad (2)$$

where, $A_C\,(Ra)$, $A_C\,(Th)$ and $A_C\,(K)$ are average activity in Bq/kg of ^{226}Ra, ^{232}Th and ^{40}K, respectively.

Equation (2) is based on the fact that 370 Bq/kg of ^{226}Ra, 259 Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same gamma dose equivalent (Stranden, 1976; Krisiuk *et al*., 1971; UNSCEAR, 1988) which implies that a radium equivalent of 370 Bq/ kg in building materials will produce an external exposure of about 1.5 mSv/y to the population (Beretka and Mathew, 1985; OECD, 1979). Though Ra_{eq} equivalent values calculated as shown in Table 2, varies from the same building materials from different locations collected. However, it is clear from this table that the Ra_{eq} values obtained is less than 370 Bq/kg which is the recommended limit by OECD.

External hazards index: To restrict the external gamma radiation dose from building materials to 1.5 mSv/ year or unity. The model below is used as dose criterion to calculate external hazard index (Beretka and Mathew, 1985; Hayambu *et al*., 1995):

$$H_{ex} = A_C(Ra)/370 + A_C(Th)/259 + A_C(K)/4810$$

where A_C (Ra), A_C (Th) and A_C (K) are the activity concentration of ^{238}U, ^{232}Th and ^{40}K expressed in Bq/kg.

External hazards index value should be less than unity for probability of risk to be negligible (Hayambu *et al*., 1995). The calculated values of external

Table 1: Activity Concentration of ^{238}U, ^{232}Th, and ^{40}K in the building materials investigated

Sample location	Sample type	Activity concentration(Bq/kg)		
		^{40}K	^{238}U	^{232}Th
Kasoa	Granite	818.51±31.92	88.51±7.04	56.38±3.56
	Clay soil	397.06±21.82	77.54±4.98	49.44±4.47
	Sandy soil	165.22±6.91	59.61±4.00	30.75±3.07
	Beach sand	137.04±5.56	45.41±2.30	33.55±2.39
	Sandcrete block	101.02±3.82	43.61±2.28	37.09±2.39
	Pebbles	372.94±16.56	33.90±3.01	27.07±2.12
Winneba	Granite	785.35±27.07	66.22±4.51	44.80±3.04
	Clay	342.47±21.31	36.36±2.55	29.08±1.98
	Sandy soil	106.38±5.27	51.82±3.43	27.38±2.45
	Beach sand	82.92±5.20	45.55±3.31	29.71±2.16
	Sandcrete block	94.36±9.25	52.46±3.50	34.05±2.50
	Pebbles	283.63±16.13	27.90±1.06	23.07±1.12
Apam	Granite	695.96±36.06	75.76±5.70	54.25±3.33
	Clay soil	364.65±21.07	83.59±3.60	35.38±2.83
	Sandy soil	107.63±9.13	53.55±3.31	28.21±2.04
	Beach sand	89.34±5.20	48.78±2.93	39.71±2.23
	Sandcrete block	95.38±4.31	50.13±4.01	38.23±2.44
	Pebbles	197.19±15.39	49.15±2.80	15.47±0.97
Otuam	Granite	677.53±25.13	67.61±4.00	55.65±3.09
	Clay soil	362.05±4.31	58.25±3.60	46.50±3.02
	Sandy soil	99.05±4.31	50.31±3.02	38.37±2.54
	Beach sand	86.89±4.51	45.55±3.31	36.21±24.44
	Sandcrete block	94.38±9.27	51.31±3.02	35.90±2.28
	Pebbles	194.22±14.51	36.26±2.55	29.10±1.98
Edumafa	Granite	599.23±26.30	62.86±3.30	34.25±2.50
	Clay soil	327.63±10.13	64.69±4.79	58.38±4.33
	Sandy soil	97.63±10.13	48.90±3.06	33.07±2.12
	Beach sand	76.28±5.37	49.23±3.07	38.17±2.54
	Sandcrete block	81.74±5.03	45.82±3.02	31.31±2.04
	Pebbles	282.68±15.07	43.55±2.31	38.21±2.06
Saltpond	Granite	795.80±31.67	95.19±3.25	42.42±1.30
	Clay soil	344.31±19.55	83.07±7.43	57.39±3.55
	Sandy soil	126.73±9.55	42.55±3.31	40.21±3.01
	Beach sand	109.05±5.31	49.31±3.02	37.37±2.54
	Sandcrete block	116.89±4.66	57.55±4.60	51.50±4.32
	Pebbles	128.89±5.81	52.20±3.97	43.43±1.30
Kormantse	Granite	549.75±27.45	76.56±4.07	50.44±4.49
	Clay	264.65±14.02	69.48±4.96	70.97±5.83
	Sandy	142.47±13.41	54.31±4.90	38.48±3.81
	Beach sand	115.25±11.07	58.61±4.03	39.75±3.60
	Sandcrete block	99.45±10.36	44.82±4.12	46.80±4.03
	Pebbles	105.62±5.81	41.59±4.32	41.38±3.56
Abandze	Granite	716.36±26.70	69.24±4.52	46.16±3.94
	Clay	305.20±18.69	67.61±4.00	38.75±3.59
	Sandy	105.05±5.32	62.96±3.90	34.35±3.50
	Beach sand	107.99±5.33	57.24±4.40	35.25±3.50
	Sandcrete block	95.63±10.13	55.42±4.83	41.99±4.34
	Pebbles	289.63±10.10	50.36±4.05	39.29±3.57
Biriwa	Granite	777.38±29.74	74.68±5.08	48.97±4.45
	Clay	256.11±12.68	71.65±5.06	47.94±4.47
	Sandy	102.02±9.82	53.82±4.27	27.58±3.48
	Beach sand	152.47±14.31	52.82±4.27	37.58±3.48
	Sandcrete block	98.55±10.29	50.33±4.02	38.27±3.54
	Pebbles	289.28±8.37	62.33±4.07	39.47±3.94
Cape coast	Granite	689.36±26.70	67.72±4.54	26.16±3.25
	Clay	299.10±14.78	59.63±4.89	44.69±4.92
	Sandy	143.73±11.30	60.71±4.40	49.85±3.97
	Beach sand	115.24±5.71	61.45±4.92	37.71±3.79
	Sandcrete block	97.92±9.66	57.88±3.95	33.92±3.25
	Pebbles	187.79±4.71	53.84±4.28	28.55±3.47
Ampenyi	Granite	943.44±34.57	97.89±6.34	74.57±5.04
	Clay	259.96±14.67	75.69±5.05	46.97±4.48
	Sandy	116.75±11.56	58.55±4.60	55.52±4.34
	Beach sand	109.98±5.34	48.05±4.45	49.41±4.57
	Sandcrete block	92.02±9.82	63.87±3.94	37.26±3.53
	Pebbles	297.51±9.39	53.84±4.29	28.59±3.49

Table 1: Continued

Komenda	Granite	778.51±31.37	105.07±9.31	46.12±3.72
	Clay	385.37±16.69	58.53±4.07	44.38±3.57
	Sandy	188.27±14.05	59.61±4.03	39.75±3.94
	Beach sand	98.75±10.39	49.17±4.12	17.51±2.99
	Sandcrete block	99.73±10.55	59.56±4.63	53.50±4.33
	Pebbles	284.89±14.65	58.88±3.95	29.93±3.28

Table 2: Calculated radium equivalent, internal and external hazards, absorbed dose rates and effective doses due to natural radionuclides in the building materials investigated

Sample location	Typeof sample	Ra_{eq} (Bq/kg)	H_{in}	H_{ex}	Absorbed dose Rate (nGy/h)	Effective dose (μSv/y)
Kasoa	Granite	232.16	0.72	0.48	109.90	539.09
	Clay soil	174.44	0.61	0.40	87.49	429.17
	Sandy soil	143.03	0.52	0.36	65.44	321.00
	Beach sand	99.94	0.37	0.25	45.72	224.26
	Sandcrete block	99.37	0.38	0.25	45.30	222.19
	Pebbles	115.66	0.34	0.24	54.91	269.35
Winneba	Granite	190.76	0.55	0.37	91.23	447.52
	Clay	104.32	0.32	0.22	49.35	242.08
	Sandy soil	99.17	0.39	0.25	44.93	220.42
	Beach sand	94.42	0.36	0.24	42.81	210.00
	Sandcrete block	108.42	0.42	0.28	49.15	241.08
	Pebbles	82.73	0.25	0.17	39.25	192.52
Apam	Granite	206.93	0.64	0.43	97.86	480.05
	Clay soil	162.26	0.60	0.37	74.74	366.62
	Sandy soil	102.18	0.40	0.26	46.28	227.03
	Beach sand	112.45	0.42	0.29	51.13	250.79
	Sandcrete block	112.14	0.42	0.30	50.97	250.04
	Pebbles	86.46	0.33	0.20	39.67	194.60
Otuam	Granite	199.36	0.60	0.41	94.52	463.68
	Clay soil	152.62	0.50	0.35	71.16	349.09
	Sandy soil	112.81	0.42	0.29	51.30	251.63
	Beach sand	104.02	0.39	0.27	47.31	232.06
	Sandcrete block	109.91	0.42	0.28	49.89	244.71
	Pebbles	92.83	0.31	0.22	43.09	211.39
Elimina	Granite	157.98	0.49	0.31	74.95	367.64
	Clay soil	173.40	0.58	0.41	80.39	394.36
	Sandy soil	103.71	0.40	0.26	47.10	231.06
	Beach sand	109.68	0.42	0.28	49.74	244.02
	Sandcrete block	96.89	0.37	0.25	43.94	215.55
	Pebbles	119.96	0.37	0.27	56.00	274.72
Saltpond	Granite	217.13	0.70	0.44	102.51	502.86
	Clay soil	191.66	0.68	0.46	88.32	433.24
	Sandy soil	109.81	0.39	0.27	50.36	247.02
	Beach sand	111.15	0.41	0.28	50.62	248.32
	Sandcrete block	140.20	0.51	0.36	63.90	313.44
	Pebbles	124.23	0.45	0.31	56.73	278.29
Kormantse	Granite	191.02	0.62	0.42	89.53	439.16
	Clay	191.35	0.66	0.47	88.19	432.60
	Sandy	120.31	0.45	0.30	54.91	269.36
	Beach sand	124.33	0.47	0.32	56.46	276.95
	Sandcrete block	119.49	0.43	0.31	54.61	267.90
	Pebbles	108.90	0.39	0.28	49.84	244.47
Abandze	Granite	195.11	0.57	0.38	93.10	456.68
	Clay	142.74	0.52	0.34	65.57	321.64
	Sandy	119.94	0.48	0.31	54.17	265.73
	Beach sand	119.39	0.45	0.30	54.44	267.03
	Sandcrete block	123.05	0.47	0.32	55.88	274.11
	Pebbles	128.82	0.43	0.30	59.92	293.94
Biriwa	Granite	204.57	0.61	0.41	97.30	477.30
	Clay	159.93	0.58	0.39	73.42	360.17
	Sandy	101.12	0.40	0.255	45.74	224.38
	Beach sand	118.30	0.44	0.29	54.09	265.34
	Sandcrete block	112.64	0.42	0.29	51.22	251.25
	Pebbles	141.05	0.50	0.33	65.18	319.72

Table 2: Continued

Cape Coast	Granite	158.21	0.48	0.30	75.43	370.00
	Clay	146.57	0.50	0.34	67.91	333.11
	Sandy	143.06	0.53	0.36	65.28	320.23
	Beach sand	124.25	0.48	0.32	56.32	276.26
	Sandcrete block	113.93	0.45	0.29	51.53	252.79
	Pebbles	109.13	0.41	0.26	50.00	245.26
Ampenyi	Granite	277.17	0.84	0.57	131.28	644.00
	Clay	162.87	0.60	0.39	74.67	366.29
	Sandy	146.93	0.54	0.38	67.00	328.65
	Beach sand	127.18	0.45	0.32	58.14	285.20
	Sandcrete block	124.24	0.49	0.32	56.08	275.10
	Pebbles	117.63	0.41	0.26	54.63	268.00
Komenda	Granite	230.97	0.76	0.48	108.49	532.18
	Clay	151.67	0.50	0.34	70.85	347.56
	Sandy	130.95	0.48	0.32	59.95	295.00
	Beach sand	81.81	0.34	0.20	36.90	181.02
	Sandcrete block	143.74	0.53	0.37	65.37	320.67
	pebbles	123.62	0.44	0.28	57.16	280.38

hazards index for these building materials ranged from 0.17 to 0.48 with the lowest dose occurring in pebbles from Winneba while highest external dose in granite sample obtained from Kasoa.

Internal hazards index: There is also radiation hazard threat to respiratory organs due to the ^{222}Rn, decay product of ^{226}Ra, and its short-lived decay product. To determine this threat the worldwide maximum radium activity content must be reduced to half of the normal limit. Therefore the model used to calculate this hazard is shown below (Beretka and Mathew, 1985; Hayambu *et al*., 1995):

$$H_{in}= A_C(Ra)/370+ A_C(Th)/259+A_C(K)/4810$$

where,A_C (Ra), A_C (Th) and A_C (K) are the activity concentration of ^{238}U, ^{232}Th and ^{40}K expressed in Bq/kg.

Table 2 indicates the values of hazard index ranging from the 0.25 to 0.72, with highest value occurring in granite from Kasoa and the minimum internal hazards index found to be 0.25 in the pebbles from Winneba.

Absorbed dose rate and effective dose rate: The absorbed dose rate D(nGy/h) was calculated for the building materials using the formula proposed by (UNSCEAR, 1993):

$$D = 0.429*A_C(U)+0.666*A_C(Th)+0.042*A_C(K)$$

where,0.429, 0.666 and 0.042 are Dose constants for ^{238}U, ^{232}Th and ^{40}K,respectively.

A_C(U), A_C(Th) and A_C(K) are the mean activity concentration of ^{238}U, ^{232}Th and ^{40}K expressed in Bq/kg.

The absorbed dose in air commuted ranged from 36.90 to 109.90 nGy/h. Most of the values obtained are greater than worldwide average value of soil (55 nGy/h) (Yang *et al*., 2005) and also UNSCEAR reported average value ranged from 18 to 93nGy/h (UNSCEAR, 1993, 2000). The values obtained by this investigated building materials are greater than the worldwide average of soil report by (Yang *et al*., 2005) and lie within the worldwide values report by (UNSCEAR,1993, 2000) with exception of granite from Kasoa, Biriwa, Abandze, Saltpond, Otuam, Komenda and Ampenyi.

Annual effective doses: The annual effective dose rate E_T (mSv/yr) from radionuclide in the building material were also calculated on the basis of the mean activity concentrations and absorbed dose rate in air. The Equation below was used to calculated Annual effective dose rate, E (mSv/yr):

$$E_T = (^{238}U,^{232}Th,^{40}K) = D*0.7(Sv/Gy)*24*365*0.8\ h/y$$

where,D is absorbed dose rate in air (nGy/h) and 0.7 is the dose conversion factor from gray to sievert (UNSCEAR, 1988), 0.8 is the indoor occupancy factor.

The annual effective dose rate varies from 181.02 to 644.00 µSv/yr. The highest annual effective dose rate occurring in granite from Ampenyi whiles the lowest annual effective dose resulting in the beach sand from Komenda. The granite from the following locations Kasoa (539.090 µSv/yr), Apam (480.05 µSv/yr), Otuam (463.68 µSv/yr), Saltpond (502.86µSv/yr), Biriwa (477.31 µSv/yr) and Ampenyi (644.00 µSv/yr) recorded the annual effective doses which are greater than the world average effective dose of 460.00 µSv/yr for soil (Yang *et al*., 2005).

CONCLUSION

NORMS and its related radiation hazards in building materials along coastal part of central region of Ghana have been studied using gamma spectrometry.

The activity concentration levels of various radionuclides were also determined. The ^{238}U content ranged from 27.90±1.06 to 97.89±6.34 Bq/kg with granite from Ampenyi measured the highest activity while pebbles bricks from Winneba recorded the lowest activity concentration. The ^{232}Th activity concentration level range from 15.47±0.97 to 70.97±5.83 Bq/kg with clay soil from Kormantse recorded the highest whiles pebbles of Apam had the lowest average activity concentration. The average activity concentration of ^{40}K ranged from 89.34±5.20 to 943.44±34 Bq/kg, with the highest activity concentration level occurring at Ampenyi and lowest level of the activity concentration also occurring in beach sand from Apam. The radium equivalent (Ra_{eq}) varied from 81.81 to 232.16 Bq/kg. The highest value occurring in granite sample from Kasoa whiles the lowest value occurring in beach sand from Komenda. The absorbed dose rate in air ranged from 36.90 to 131.29 nGy/h with the maximum dose rate resulting in granite from Ampenyi whiles minimum dose rate in air occurring in beach sand from Komenda. The annual effective dose rate varies from 181.02 to 644.00 μSv/yr. The highest annual effective dose rate occurring in granite from Ampenyi whiles the lowest annual effective dose resulting in the beach sand from Komenda.

The activity concentration of ^{238}U, ^{232}Th and ^{40}K investigated are found to be normal and within the average worldwide ranges. The Radium equivalent, external and internal indexes, absorbed dose rate in air and annual effective doses calculated are within the values found in other countries. The values were also found to be within the limit for public exposure control set by the ICRP 60 and OECD (ICRP 60, 1991; OECD, 1979). Thus, no significant radiological hazards arise from using building materials along coastal part of central region of Ghana for construction of houses.

The results may not reflect the real situation in all types of building materials in the selected studied areas. For more accurate results that better may represent the regions of the country, detailed studies can be carried out for all the different types of building materials used, using higher number of samples. This study can also be used as a reference for more extensive studies and the results serve as a source of information to assist in the formulation of regulatory guidelines for decision-making in Ghana.

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