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Research Article

RADIOLOGICAL HAZARD ASSESSMENT OF BEACH SANDS FROM LANDING BEACHES IN THE VOLTA REGION OF GHANA

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Abstract

Hazards attributable to the natural radionuclides present in beach sands, from ten (10) landing beaches in the Volta Region of Ghana, was assessed in this study. The terrestrial radiation exposure levels on the beaches, in addition to hazards humans may face when exposed to the analyzed sands were determined. Gamma-spectrometry was used to assess specific activities of radionuclides in the samples. Three different radiological hazard indices analogous to radiation hazards were estimated. Total absorbed gamma dose rate in the air and equivalent annual effective dose were assessed. The resulting specific activities range from 1.87 - 17.53 Bq Kg^{-1} for ^{226}Ra, 3.84 - 24.81 Bq Kg^{-1} for ^{232}Th and 77.40 - 1103.90 for ^{40}K, while mean values of 30.02 nGy h^{-1}, 0.18 mSv y^{-1}, 61.24Bq kg^{-1}, 0.17 and 0.19 were obtained, for absorbed dose rate, annual external effective dose, radium equivalent activity, external hazard index and internal hazard index respectively. The sands from the beaches studied cannot be considered as a radiological hazard to human safety and health.

Introduction

The importance of coastlines is clearly demonstrated by the high human settlements within 150 km of the shores. More than 44% of the world's population live within this zone [1]. The multiplicity of use of the coast and coastal resources also attests to the importance of this area. Coastal tourism, one of the most common uses of the coast, has been growing exponentially [2]. Around the world, well designed tourism development projects have produced socioeconomic outcomes, allowing the local populace attain and sustain a relatively high standard of living [3]

In Ghana, the most common uses of the beaches are for recreation by holiday makers or tourists and as landing places for docking of canoes by fishermen.

Marine fishing is considered one of the most hazardous professions all over the world. Exposure to cold winds, rough seas, extensive use of raw strength, and high injury occurrence, unexpected and unpredictable threats, the frequent failure of equipment, everyday psychological stress, and constant economic pressure are some hazards of the fishing occupation. The variety of hazards, however, depends significantly on factors such as; culture, geology and geographical-climate of the location. Fishermen, fish mongers and other users of beaches are also constantly exposed to ionizing radiation.

Beach dwellers are exposed to gamma radiation everyday of their lives, directly from the beach sands. Radioactivity from terrestrial radionuclides is normally present at trace amounts. Higher radiation levels can be found in soils and sands derived from igneous rocks, phosphate sedimentary rocks, dark shale and metamorphic rocks [4]. Decay products from ^{238}U and ^{232}Th series, plus ^{40}K play a major part as external sources of exposure due to NORM radiation on the human body. Totally absorbed gamma dose rate attributable to naturally-occurring radionuclides can be calculated from the specific activity of each radionuclide[5, 6].

To appreciate the radiological implication of radiation exposure and inhalation of radon and its daughter elements, there is the need to study the distribution of terrestrial radionuclides [6]. Specifically, it is imperative to evaluate the possible radiological hazards from beach sand used in the construction of houses. Consequently, it is important to assess dose from NORMs since they contribute most external dose to the world population [4, 7].

Dose rates fluctuate subject to concentration of the decay products of ^{238}U, ^{232}Th, and ^{40}K, existing in the beach sand. This fluctuation depends on the geology of the location.

This study aimed at measuring the levels of NORMs in the major landing beaches along the Atlantic coast of the Volta Region, using HPGe spectrometers to evaluate activity levels of NORMs as well as determine the radiation hazards associated with beach sands present in these areas.

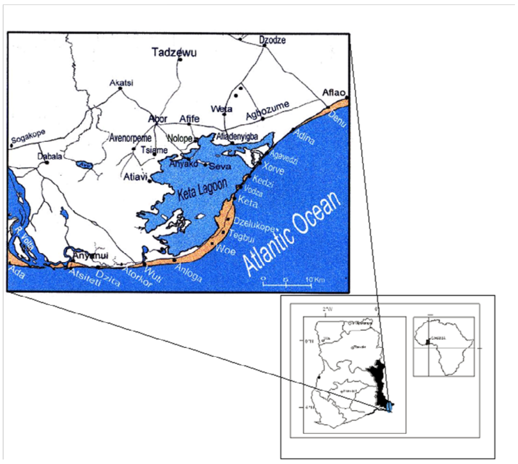

Figure1: Map of Volta Region showing the study area.

From the obtained activity data, radium equivalent activity (Ra_{eq}), internal hazard index (H_{in}) and the external hazard index (H_{ex}) were calculated. Furthermore, the absorbed dose rate in air (outdoors) 1 m above the ground was estimated, and the annual effective dose (mSv yr^{-1}) outdoors and indoors calculated as the measure of human exposure to radiation. [4–6] The obtained values were compared to the recommendation of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the Organization for Economic Co-operation and Development (OECD).

Experimental Procedure

This study covered ten of the landing beaches in the Volta Region of Ghana (Figure.1). The Volta Region forms the eastern part of Ghana, and shares boundary with the Republic of Togo. The Atlantic Ocean forms the southern boundary of the region. The vegetation of the region is dominantly savanna with a land size of about 18090 square kilometers.

Five beach sand samples were collected from, each beach at depths between 5 and 25cm. The sand samples were spread on trays and allowed to dry at room temperature for 14 days in the laboratory. A slow-airflow drying cabinet, at 50°C, was used for oven-dry the samples for 24 hours (with), grounded, homogenised, and a sieve with 1 mm mesh was used to screen samples. The samples were then packed into one liter Marienelli beakers. Approximately 1kg of each sample was used. The Marienelli beakers, with the samples, were sealed for 30 days, with the assumption that the long-lived parent nuclides will establish secular equilibrium with their respective short–lived daughters before measurements [8].

Activity measurements were performed by gamma-ray spectrometry. The spectrometry system employed for this work consist of a High Pure Germanium Detector (HPGe), cooled by liquid nitrogen in a dewar. The spectrum acquisition and evaluation was done using a detector assembly attached to a desk top computer running Maestro 32 MCB configuration software. To reduce background radiation, the detector was placed within a 5 cm thick cylindrical lead shield which is lined with 3mm thick layers of cadmium, plexilglass and copper. This arrangement helps in the absorption of X- rays generated in the shield.

The detector system was calibrated using the multinuclide reference standard solution. The standard was measured in the 1.0 litre Marinelli beaker. Preceding sample analysis, energy and efficiency calibrations were done to facilitate identification and quantification of the radionuclides

The standard used for the calibrations consisted of a liquid mixed radionuclide solution with the following corresponding energies; ^{241}Am (59.54 keV), ^{109}Cd (88.03 keV), ^{57}Co (122.06 keV), ^{139}Ce (165.86 keV), ^{203}Hg (279.20 keV), ^{113}Sn (391.69 keV), ^{85}Sr (514.01 keV), ^{137}Cs (661.66 keV), ^{60}Co (1173.2 keV and 1332.5 keV) and ^{88}Y (898.04 keV and 1836.1 keV): and was supplied by the International Atomic Energy Agency. The measurement, geometry used for samples were the same as that of the standard. A dedicated software program, Maestro 32 MCB, was used in the analysis of each measured gamma-ray spectrum.

The concentration of ^{232}Th was determined using the average concentrations of ^{212}Pb (238.6 keV) and ^{228}Ac (911.1 keV) while ^{226}Ra was determined from the average concentrations of the ^{214}Pb (351.9 keV) and ^{214}Bi (609.3 and 1764.5 keV) decay products [9, 10, 11].

The activity concentration (A) in Bq kg^{-1} in the beach sand samples were calculated using the relation:

$$A = \frac{N_p}{P * \varepsilon * m} \qquad (1)$$

where N_p = sample(cps) – BG(cps), P is the abundance of the gamma line, ε is the measured efficiency for each gamma line and m the mass (kilograms) of the sample.

The absorbed dose rate 1 m above the ground (nGy h^{-1}) due to Ra, Th and K was calculated using the following equation [1].

$$D(nGyh^{-1})=0.0417\,A_K+0.462\,A_{Ra}+0.604A_{Th} \quad (2)$$

The annual effective dose was calculated from the absorbed dose rate using the dose conversion factor of 0.7 Sv/Gy [4].

For Indoor:

$$D\,(nGyh^{-1})*8760*0.8*0.7\,Sv\,Gy^{-1} \quad (3)$$

For Outdoor:

$$D\,(nGyh^{-1})*8760*0.2*0.7\,Sv\,Gy^{-1} \quad (4)$$

Where 0.8 and 0.2 are the occupancy factors for indoor and outdoor respectively and 8760 is the total time of the year in hours. 0.7 Sv h^{-1} is the conversion factor for external gamma radiation.

Radium equivalent activity indices were calculated using the relation [9].

$$Ra_{eq}=A_{Ra}+1.43\,A_{Th}+0.077\,A_K \quad (5)$$

The constants represent conversion factors, in nGy h^{-1} per Bq kg^{-1}, estimated using Monte Carlo method and A_{Ra}, A_{Th} and A_K are the specific activities (Bq kg^{-1}) of ^{226}Ra, ^{232}Th and ^{40}K respectively. The radiation hazard becomes insignificant if resulting maximum radium-equivalent activity equals 370 Bq.kg^{-1}.

External hazard indices were calculated using the equation [9]

$$H_{in}=\frac{A_{Ra}}{159}+\frac{A_{Th}}{295}+\frac{A_K}{4810} \quad (6)$$

where A_{Ra}, A_{Th}, and A_K are the specific activities of the radionuclides.

For the radiation hazard to be inconsequential, the value of this index must not be greater or equal to one.

The internal hazard indices were calculated using the equation [9]

$$H_{in}=\frac{A_{Ra}}{159}+\frac{A_{Th}}{295}+\frac{A_K}{4810} \quad (7)$$

The internal hazard index should also be less than unity if the radiation hazard from internal exposure to radon and its daughter products in human body are to be considered as safe.

Results and Discussion

The activity concentration of ^{226}Ra and ^{232}Th series, as well as naturally occurring ^{40}K in sand samples, taken from the ten beaches are low (Table 1).

Beaches	$A_{sp}(BqKg^{-1})$		
	^{232}Th	**^{226}Ra**	**^{40}K**
Aflao	16.26	18.99	104.90
Denu	10.57	24.81	1103.90
Kedzi	1.87	3.84	524.30
Keta	6.87	15.33	647.40
Tegbi	2.26	6.01	364.00
Woe	6.84	11.43	127.50
Anloga	14.33	16.63	439.80
Whuti	2.42	7.26	77.40
Dzita	9.45	18.14	650.40
Anyanui	17.53	20.74	105.90
Minimum	1.87	3.84	77.40
Maximum	17.53	24.81	1103.90
Average	8.84	14.32	414.55

Table 1. Mean Specific Activities of ^{226}Ra, ^{232}Th and ^{40}K in sand from selected beaches.

A Minimum activity concentration of 2.26 Bq kg^{-1} was determined for ^{226}Ra in the sand sample from the Tegbi Beach, while the maximum value of 17.53 Bq kg^{-1} was found in the sand from the Anyanui Beach. The activity concentrations of ^{232}Th were in the range 3.84 – 24.81 Bq kg^{-1}. Kedzi Beach registered the minimum value while the Denu Beach registered the maximum. The content of ^{40}K had the lowest value of 77.40 Bq kg^{-1} for the Whuti Beach sand sample. Table 2 compares the specific activities of ^{232}Th, ^{226}Ra and ^{40}K (Bq kg^{-1}) in sand samples from the Volta Region to other studies in different beaches of the world.

Location	A_{sp}(BqKg^{-1})		
	^{232}Th	^{226}Ra	^{40}K
Beach sand, Volta Region, Ghana	3.8-24.8	1.9-17.5	77.4-1104
Preta beach Southeastern Brazil	128-349	54-180	47-283
Dois Rios beach, South-eastern Brazil	12-87	6-78	269-527
Visakhapatnam, India	300-600	100-400	-
Northeast Coast, Spain	5-44	5-19	136-1087
Ullal, India	1842	374	158
Kalpakkam, India	352-3872	36-258	324-405
Red seashore sediment, Egypt	2.3-221.9	95.3-105.6	98-1011
Costal sand, Egypt	44.3-95.6	32.2-63.7	96-102
Beach sand, Al-Maidan, North Sinai,	146	108	77
Seabed sand, Tuen Mun Hong Kong	29.8	27.7	1210
Coastal Karnataka	489.6	249.2	55
Black sand, Brazil	25-2412	190-36620	
Zircon, Bangladesh	1324	6439	472
Global average soil	10-50 40	7-50 35	100-700 370
Global average soil	8–160 32	4–130 45	100 – 700 420

Modified from reference [8]

Table 2: Comparison of Specific Activities of ^{232}Th, ^{226}Ra and ^{40}K (Bq kg^{-1}) in sand samples from Volta Region and other studies in different beaches of the world.

Beach sands are used by the fishermen and the local people as construction material. There is the need, therefore, to evaluate the hazards to humans from gamma radiation within the beach sands. The experimental results of Radium equivalent activity (Ra_{eq}) in Bq kg^{-1}, External hazard index (H_{ex}), and Internal hazard index (H_{in}) obtained are presented in Table 3.

Beaches	R_{eq} (Bq kg^{-1})	H_{ex}	H_{in}
Aflao	51.49	0.14	0.18
Denu	131.04	0.35	0.38
Kedzi	47.74	0.13	0.13
Keta	78.64	0.21	0.23
Tegbi	38.89	0.11	0.11
Woe	33.01	0.09	0.11
Anloga	71.97	0.19	0.23
Whuti	18.76	0.05	0.06
Dzita	85.47	0.23	0.26
Anyanui	55.34	0.15	0.20
Average	61.24	0.17	0.19

Table 3. Radium equivalent (R_{eq}), External hazard indices (H_{ex}) and Internal hazard indices (H_{in}) of the studied sa ples.

The values show that average Ra_{eq} (61.24 Bq kg^{-1}) obtained are lower than the value internationally accepted (370 Bq kg^{-1}). The external and internal hazard indices have values of 0.17 and 0.19 respectively. All studied beaches have Ra_{eq}, H_{ex} and H_{in} lower than the international accepted values.

The mean values of annual effective doses outdoor (Table 4)

Selected Beaches	Annual External Effective Dose (mSv/y)		
	Indoors	Outdoors	Total
Aflao	0.11	0.03	0.14
Denu	0.32	0.08	0.40
Kedzi	0.12	0.03	0.15
Keta	0.19	0.05	0.24
Tegbi	0.10	0.02	0.12
Woe	0.08	0.02	0.09
Anloga	0.17	0.04	0.21
Whuti	0.04	0.01	0.05
Dzita	0.21	0.05	0.26
Anyanui	0.12	0.03	0.15
Average	0.15	0.04	0.18

Table 4. Mean values of annual external effective doses of selected beaches.

in all the beaches investigated, were lower than the world-wide average of 0.07 mSv y^{-1} published in UNSCEAR 2000 [4].

Sands from the beaches studied do not preset any radiological hazard to fishermen and users of the beaches. This is due to the low values of gamma dose rates from the samples investigated as compared to the dose limit of 1mSv y^{-1} for the general public. The annual external effective dose rates varied from 0.05 to 0.40 mSv y^{-1}, with an average value of 0.18 mSv y^{-1}. The averge

annual external effective dose from terrestrial radionuclides published for normal background areas is 0.46 mSv y^{-1} [4, 8]. Therefore, corresponding values obtained for the beaches of the Volta region are below the average normal background doses received from terrestrial radionuclides globally**.**

Conclusion

Data obtained for external and internal hazard indices of the samples vary from 0.05-0.35 and 0.11-0.26 respectively, whiles radium equivalent activity ranges from 18.76 to 131.04 Bq. kg^{-1}. These values are less than the internationally approved values (<1 for H_{ex} and H_{in} , and <370 Bq.kg-1 for Ra_{eq}) [4]. The data obtained suggests that beach sand samples from the study area could not be considered as a radiological hazard to people who are exposed to sand from these beaches. The ten landing beaches are at representative background radiation level.

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