Available online at www.elixirpublishers.com (Elixir International Journal)

Pollution

Elixir Pollution 41 (2011) 5761-5765

ISSN: 2229-712X

Preliminary study of natural radioactivity in soils of some selected towns along the bosumtwi lake, Ghana

E.O. Darko[1], S. Adu[1], A. R. Awudu[1], G. Emi-Reynolds O.K. Adukpo[1], A. Faanu[1], M. K. Obeng[1], L.A. Sarsah[2], E. Quarshie[3], F. Otoo[1] and A. Amekudzie[1]

[1]Radiation Protection Institute, Ghana Atomic Energy Commission, Box LG80, Legon, Ghana.

[2]Nuclear Medicine and Radiopharmacy Centre, Radiological and Medical Sciences Research Institute, Ghana Atomic Energy Commission, Box LG80, Legon-Accra, Ghana.

[3]Nuclear Chemistry and Environmental Research Centre, National Nuclear Research Institute, Ghana Atomic Energy Commission, Box LG80, Legon-Accra, Ghana.

ARTICLE INFO

Article history:

Received: 19 September 2011;

Received in revised form:

16 November 2011;

Accepted: 28 November 2011;

Keywords

Activity Concentration,
Effective dose,
External hazard index,
Natural radioactivity,
Gamma spectrometry,
Radium equivalent.

ABSTRACT

The level of natural radioactivity in soils of some selected towns around Lake Bosumtwi of Ashanti region of Ghana have been determined. Thirteen Samples from different locations close to the catchment area of the lake were collected for determination of NORM activity concentrations using high-purity germanium (HPGe) gamma spectrometer. Activity concentration of ^{226}Ra, ^{232}Th, and ^{40}K ranged from 2.9 ± 0.14 Bq/kg to 168.2 ± 0.6 Bq/kg with an average of 31.2±0.3 Bq/kg, 0.4 ± 0.1 Bq/kg to 108.4 ± 9 Bq/kg with an average of 11.9 Bq/kg and 20.4 ± 3 Bq/kg to 340.8 ± 12 Bq/kg with an average of 134.8± Bq/kg, respectively. The results obtained were also in good agreement with studies from other countries in the region and therefore can be used to enhance present radioactivity database. The calculated external hazard values ranged from 0.02 Bq/kg to 0.56 Bq/kg with the mean of 0.15 (less than unity) showed no risk of external hazard to the inhabitants and Tourist visiting the catchment.

Introduction

Natural radioactivity in soils comes from U and Th series and natural K. The study of the distribution of primordial radionuclides allows the understanding of the radiological implication of these elements due to the ɣ-ray exposure of the body and irradiation of lung tissue from inhalation of radon and its daughters (Alam et al., 1999; Singh et al., 2005). The lake Bosumtwi basically serves as a recreational ground where people go on holidays for fun and as a tourist sites. It therefore important to assess the radiation hazards arising from the soil or sand. The assessment of gamma radiation dose from natural sources around towns of the lake is of particular importance as natural radiation is the largest contributor to the external dose of the world population (UNSCEAR, 1993, 2000). These dose rates vary depending upon the concentration of ^{238}U, ^{232}Th, their daughter products and ^{40}K, present in soil, sands and rocks, which in turn depend upon the local geology of each region in the world. The main sources of exposure to ionizing radiation are of the natural and artificial origin. Naturally occurring radionuclide are found everywhere around us in the environment and as a result, certain amount of radioactivity is always present in any substance. In most naturally occurring radioactive materials (NORM), several or all of the radioactive isotopes of the three primordial decay series (^{235}U, ^{238}U and ^{232}Th) are present in small concentrations in the natural matrix.

In the natural undisturbed environment, the radionuclides in the decay series are more or less in radiological equilibrium. However, this equilibrium becomes disturbed due to human activities, resulting in either an enrichment or depletion of some of the radionuclides concentrations compared to the original matrix.

The radiological impact of NORM on humans depends strongly on the process which produces the NORM and pathways by which it is transferred from the source to humans (Karunakara, N et al 2001). There are several human activities that could lead to technological enhancement of NORM. These activities include mining, farming, fertilizer manufacturing and use, phosphate manufacturing and use, burning of fossil fuel etc and use of buildings as dwellings and work places can lead to significant exposure to NORM (Karunakara, N et al 2001).

The UNSCEAR report 2000 evaluates that a global average exposure to natural radiation sources is 2.4 mSv/y. This value consists of 0.39 mSv/y of the exposure to cosmic rays including cosmologenic radionuclides, 0.48 mSv/y external exposure due to terrestrial radionuclides that occur in the earth's crust, 1.26 mSv/y of internal exposure due to radon inhalation and 0.29 mSvy^{-1} of internal exposure due to food intake. The largest contributors to these exposures are ^{238}U and ^{232}Th series nuclides that account for about 70% of the sources (UNSCEAR 2000). Even though the levels of exposure to NORM are low, studies are inconclusive on the possible effects from low doses of radiation.

In this study, Bosumtwi Lake is chosen because of its great importance based on the different uses of the lake and its surroundings, namely recreation, tourism, fisheries, etc. The Lake has economic, social and environmental significance. To predict the radiological impacts of environmental radioactivity, it is necessary not only to define their concentrations but also their behaviour in different environmental systems. Anxiety

Tele:
E-mail addresses: darkoeo@yahoo.com

arose in the international community concerning the future and in particular the possibility of radioactive pollution of the lake.

Despite the renewed research activities at and around Bosumtwi, no data on the natural radioactivity levels of the crater and its environs has been published. As the Bosumtwi impact crater is clearly the most interesting geological feature in Ashanti Region, which however also enjoys considerable geological interest because of known gold deposit in the wider region and strong gold exploration interest in the actual crater area, the current study will provide a data on the NORM in the Lake which will form the base line information when there is a change in radioactivity levels in the lake and its environs.

Description of the Studied Area

Lake Bosumtwi is a natural inland freshwater lake in the Ashanti Region of Ghana. Bosumtwi occupies a meteorite impact crater in southern Ghana (fig 1a), which was formed ca. 1.07 Ma (Koeberl et al., 1997). It is located at 06°32'N and 01°25'W about 30 km south-east of Kumasi the capital of the Ashanti Region of Ghana in the Northern tip of the Adansi mountains in the lowland forest zone of Ghana, and is excavated in 2 Ga old metasediments and metavolcanics of the Birimian Super group (Talbot and Johannessen, 1992). The 10.5 km diameter crater is almost completely filled by Lake Bosumtwi, with the crater rim rising about 250–300 m above the lake level. It is surrounded by a slight and irregular circular depression and an outer ring of minor topographic highs. The impact origin of the crater has been established from the presence of suevitic breccia (containing shocked minerals) around the crater, as well as from occurrences of coesite, Ni-rich iron spherules, and baddeleyite in the vesicular glasses within the suevites (Shanahan et al, 2005).

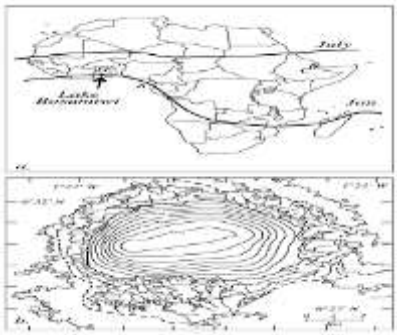

Fig.1: (a) The location of Lake Bosumtwi in southern Ghana. Dark lines represent the approximate location of the Intertropical Convergence Zone (ITCZ) in summer and winter. (b) Bathymetric map of Lake Bosumtwi, from Brooks et al. (2005).

The lake exhibits a radial drainage system of 106 km^2 and a maximum depth of 70 m; 99 ma above sea level (fig 1b). Lake Bosumtwi covers an area of about 52 km^2 (Turner et al., 1995). It is hydrologically closed, with no connection to the regional groundwater aquifer, no river or stream inflow originating outside of the crater, and no surface water outflow except when the lake reaches a spillway located 110 m above the present lake surface (Turner et al. 1996a). Mean annual temperatures are ca. 26.7 °C, and the lake receives 1260 mm of annual rainfall (based on 1990–2000 averages at Kumasi), with most occurring during the two rainy seasons in April–July and September–October. The mean climatology has changed significantly over the last half century, with substantial decreases in precipitation and increases in temperature. The lake level is very sensitive to small changes in rainfall and other climatic parameters, such as annual mean temperature and evaporation.

Lake Bosumtwi is a fresh closed lake playing an important role in the lives of more than 24 surrounding communities. It is used for commercial fishery and also for recreation and has a great potential for future agricultural development. The lake also serves as one of the primary tourist sites for the country. The lake is one of the main sources of livelihood for 24 communities living around and they heavily depend on the fish catch for their income and food (protein). Besides fishing, they depend on the aquatic resource for drinking water and irrigation water for agricultural activities.

The lake also provides the basis of other social and economic opportunities such as transportation and tourism. The Bosumtwi Forest Reserve, which is near the Ankaase community at Lake Bosumtwi (Fig. 2), and has an area of 140 km^2, is a legally protected area that consists of semideciduous tropical rainforest and provides a typical natural environment of the sort that attracts ecotourists.

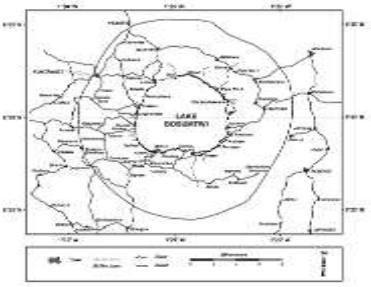

Figure 2: Lake Bosumtwi and surrounding Towns

Materials and Methods

Sampling Areas.

Soil sample were taken from 13 selected towns out of 24 towns at random around the lake. These towns are namely: Pipie No. 2, Abono, Obo, Nkowi, Dompa, Atafram, Anyniatiase, Adwafo, Aborodwon , Abease , Amakom , Duase and BrodeKwano (fig 2).

Sample Collection and Preparation

The soil from respective towns around the lake Bosumtwi were collected and transported to the laboratory in labeled polythene bags. The samples were well mixed after removing extraneous materials such as roots, mat portions, pieces of stones and gravel. Samples were weighed and then dried in an oven at 105 ^{o}C overnight and re-weighed to find the water content. After mixing thoroughly, the samples were shaken in a sieve shaker and particle sizes of <250 microns were obtained. Sieved samples were sealed in 1000 ml Marinelli beakers and stored for a minimum period of 30 days to allow ^{226}Ra to maintain radioactive equilibrium between ^{226}Rn and its daughters. Proper sealing was done to avoid ^{222}Rn escaping.

Sample Analysis

The samples were analyzed using an ORTEC high resolution gamma-spectrometry system. The spectrometer consists of a High Purity Germanium (HPGe) detector couple to a desk top computer provided with a Canberra S100 multichannel analyzer (MCA) in conjunction with a Maestro-32 multi-channel buffer (MCB) configuration software for spectrum acquisition and evaluation. 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 brick surrounds the detector to prevent external background radiation reaching the detector. The detector is coupled to a Canberra 1510 signal processing unit which contains the power supply, amplifier and analogue to digital converter. Digitized

counts are collected in a Canberra S100 multi-channel analyzer. The detector is cooled with liquid nitrogen at -196 ^{0}C (77K) provided in a 25 liter Dewar. The ambient temperature around the detector was 16^{o}C during the period of measurement. The relative efficiency of the detector is 25 % with energy resolution of 1.8 keV at gamma ray energy of 1332 keV of ^{60}Co.

The energy and efficiency calibrations of the detector were performed using mixed radionuclide standard of density 1.0 g cm^{-3} in a 1.0 L Marinelli beaker manufactured by Deutscher Kalibrierdienst (DKD-3), QSA Global GmBH, Germany. Photopeak efficiency calibration was performed by acquiring a spectrum of the calibration standard until the count rate at the peak of total absorption could be calculated with statistical uncertainty of less than 1% at a confidence level of 95%.

The net count rate was determined at the photopeaks for all the energies used for the determination of the efficiency of the calibration standard at the time of measurement. The efficiency at each energy was plotted as a function of the peak energy and extrapolated to determine the efficiencies at other peak energies for the measurement geometry using the relationship (O.K Adukpo, et. al, 2010).

$$\ln \varepsilon(E_\gamma) = 0.206 - 0.487(\ln E_\gamma) \quad (1)$$

where 0.206 and 0.487 are calibration constants for the geometry used and Eγ is the gamma energy.

Background counts were taken for the same period and density corrections made where appropriate. The samples were counted for 86400 seconds. The specific activity concentrations of ^{238}U, ^{232}Th and ^{40}K in Bq/kg for the soil samples respectively were determined. The ^{226}Ra activity was determined by taking the mean activity of the two separate photo peaks of the daughter nuclides: ^{214}Pb at 352.0 keV and ^{214}Bi at 609.3 keV, ^{232}Th was determined using photo peaks of ^{228}Ac at 911.1 keV and the photopeak of ^{212}Pb at 583.1 keV and ^{40}K was directly determined using 1460.8 keV photopeak. The activity concentrations (Bq/kg) of ^{40}K, ^{238}U and ^{232}Th, respectively were computed using the relationship (Beck, et. al, 1972).

$$A_{sp} = \frac{N_{sam}}{P_E . \varepsilon . T_c . M} \quad (2)$$

where; N_{sam} - background corrected net counts of the radionuclide in the sample, P_E - gamma ray emission probability (gamma yield), ε - total counting efficiency of the detector system, T_c - sample counting time, and M - mass of sample (kg).

Results and Discussion

Table 1 shows the result of measurements activity concentration of ^{226}Ra, ^{232}Th, ^{40}K. Table 2 shows the calculations of radium equivalent, external hazards, absorbed dose rates and effective doses due to natural radionuclides in the soil samples and Table 3 shows the comparison of this study to studies done in other countries.

The activity concentration of ^{226}Ra ranged from 2.9±0.14 Bq/kg in sample from Aborodwon to 168.2±0.6 Bq/kg from Atafram with an average of 31.2±0.3 Bq/kg. The activity concentration of ^{232}Th ranged from 0.4±0.1 Bq/kg (in the soil samples) from Amakom to 108.4±9 Bq/kg (in the soil samples) from Pipie No. 2 with an average of 11.9±4 Bq/kg. The activity concentration of ^{40}K ranged from 20.4±3 Bq/kg (in the soil samples) from Aborodwon to 340.8±12 Bq/kg (in the soil sample) from Atafram with an average of 134.8±6 Bq/kg.

It is interesting to note that the soil samples of the Dompa, Pipie No. 2 and Atafram showed higher specific activities of ^{226}Ra, ^{232}Th and ^{40}K respectively as compared to the other samples. The higher activities are attributed to the fact that these areas are underlain by granitic rocks with relatively thin soil cover since it is well known that, granites contain high concentration of uranium, thorium and potassium (Ivanovich and Harmon, 1982).

Radium equivalent activity:

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

$$Ra_{eq} = AC\ (Ra) + 1.43 * AC\ (Th) + 0.077 * AC\ (K) \quad (3)$$

where, AC (*Ra*), AC (*Th*) and AC (*K*) are average activity in Bq/kg of ^{226}Ra, ^{232}Th and ^{40}K, respectively. Equation (3) 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 the soil sample will produce an external exposure of about 1.5 mSv to the population (Beretka and Mathew, 1985; OECD, 1979). Though Ra_{eq} equivalent values calculated as shown in Table 2, varies from the same soils 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 check the level of restriction to the external gamma radiation dose from soils of the studied area to 1 mSv/ year or less. The model below is used as dose criterion to calculate external hazard index (Beretka and Mathew, 1985; Hayambu *et al*., 1995):

$$H_{ex} = AC(Ra)/370 + AC(Th)/259 + AC(K)/4810 \leq 1 \quad (4)$$

where AC(Ra), AC(Th) and AC(K) are the activity concentration of ^{226}Ra, ^{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 hazard index ranged from 0.02 Bq/kg to 0.56 Bq/kg with the lowest dose occurring soils at Aborodwon while highest external dose occurred at Atafram (Table 2).

Absorbed dose rates

From the results of ^{226}Ra, ^{232}Th and ^{40}K activities in the surface soil (Table 1) the gamma dose rates in air were calculated using the dose coefficients (nGy/h per Bq/kg) 0.462, 0.604 and 0.0417 given in UNSCEAR (2000) for ^{226}Ra sub-series, ^{232}Th series and ^{40}K respectively and by assuming secular equilibrium between ^{238}U and ^{226}Ra. The absorbed dose is given by:

$$D = [(0.462 * A_{Ra}) + (0.604 * A_{Th}) + (0.0417 * A_K)]\ nGy/h \quad (5)$$

where, A_{Ra}, A_{Th} and A_K are the concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively, in Bq kg^{-1}. It may be noted that about 98% of the external dose from ^{238}U series is delivered by ^{226}Ra sub-series. Therefore, the disequilibrium, if any, between ^{226}Ra and ^{238}U does not affect the dose estimation from the measurement of ^{226}Ra. The absorbed dose values thus calculated are presented in Table 2. The total absorbed dose delivered by these radionuclides ranged from 10.51–227.67nGy/h with a mean value of 77.8 nGy/h which is comparable with the world average value of 51 nGy/h (UNSCEAR, 2000).

Annual effective doses: The annual effective dose rate ET (mSv/yr) from radionuclide in the soils 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, ET (mSv/yr):

ET = (^{238}U,^{232}Th,^{40}K) = D*0.7(Sv/Gy)*24(h/d)*365(d/y)*0.2

where,D is absorbed dose rate in air (nGy/h) and 0.7(Sv/Gy) is the dose conversion factor from gray to sievert (UNSCEAR, 1988), 0.2 is the outdoor occupancy factor. The effective doses thus calculated in (Table 2) are found to vary in the range 0.13–2.71 mSv with a mean of 0.90 mSv.

Conclusion

The results obtained indicate that the study area has a background radiation level that is within the natural limits and shows no significant departure from other parts of the country. Although the study has not covered the entire external radius of the lake, this is the first report on the data on radionuclides in soil of the lake. The results show that the concentrations of ^{226}Ra, ^{232}Th and ^{40}K in soil of Lake Bosumtwi are comparable to the reported worldwide range and mean values.

Acknowledgement

The authors are grateful to the Radiation Protection Institute of the Ghana Atomic Energy Commission for the use of their facilities for this study.

References

1. Adukpo, O.K. Ahiamadjie, H. Tandoh J.B. Gyampo, O. Nyarku, M. Darko, E.O. Faanu A. Dampare, S.B. Assessment of NORM at diamond cement factory and its effects in the environment. J Radioanal Nucl Chem. DOI 10.1007/s10967-010-0844-6

2. Alam, M.N., Chowdhury, M.I., Kamal, M., Ghose, S., Islam, M.N., Mustafa, M.N., Miah, M.M.H., Ansary, M.M., 1999. The ^{226}Ra, ^{232}Th and ^{40}K activities in beach sand minerals and beach soils of Cox's Bazar, Bangladesh. J. Environ. Radioact. 46, 243–250.

3. Anagnostakis, M.J., Hinis, E.P., Simopoulos, S.E., Angelopoulos, M.G., 1996. Natural radioactivity mapping of Greek surface soils. In: Hopke, Philip K. (Ed.), The Natural Radiation Environment IV. Environment International, vol. 22, pp. 3–8. Suppl. 1.

4. Beck, H.L Decompo J, Gologak J (1972) In situ Ge (ii) and NaI(Tl) gamma ray spectrometry. Health and Safety Laboratory AEC: Report HASL 258, New York

5. Beretka, J. and P.J. Matthew, 1985. Natural Radioactivity of Australian Building materials, industrial wastes and by - products. Health Phys., 48(1): 87-95.

6. Brooks, K., Scholz, C.A., King, J.W., Peck, J., Overpeck, J.T., Russell, J.M., Amoako, P.Y.O., 2005. Late-Quaternary lowstands of lake Bosumtwi, Ghana: evidence from high-resolution seismic-reflection and sediment-core data. Palaeogeography, Palaeoclimatology, Palaeoecology 216, 235–249.

7. Hayambu, P., M.B. Zaman, N.C.H. Lubaba, S.S. Munsanje and D. Muleya, 1995. Natural radioactivity in Zambian building materials collected from Lusaka. J. Radioanal. Nucl. Chem., 199(3): 229-238.

8. Ivanovich, M., Harmon, R.S., 1982. Uranium series disequilibrium – applications to environmental problems. Clarendon Press, Oxford, pp. 51–5.

9. Merdanoglu, B., Altinsoy, N., 2006. Radioactivity concentrations and dose assessment for soil samples from Kestanbol granite area, Turkey. Radiation Protection Dosimetry 121 (4), 399–405.

10. Michail S. Mel.Gunov1, Vsevolod M. Gavshin1, Fedor V Sukhorukov1, Ivan A. Kalugin1, Vladislav A. Bobrov1 and Jean Klerkx2. Anomalies of Radioactivity on the Southern Bank of the Ysyk-Köl Lake (Kyrgyzstan)

11. Organization for Economic Cooperation and Development (OECD), 1979. Exposure to Radiation from the Natural Radioactivity in Building Materials. OECD, Paris.

12. Karunakara, N., V.R.K. Murty. 2008. Natural radioactivity in the soil samples of Botswana. Radiation Measurement 43, 1541–1545.

13. Karunakara, N, Somashekarappa, H.M., Siddappa, K., 2005. Natural radioactivity in South West Coast of India. International Congress Series 1276, 346–347.

14. Karunakara, N., Somashekarappa, H.M., Avadhani, D.N., Mahesh, H.M., Narayana, Y., Siddappa, K., 2001. ^{226}Ra, ^{232}Th and ^{40}K concentrations in soil samples of Kaiga of South West Coast of India. Health Physics 5, 470–476.

15. Koeberl C., Bottomley R. J., Glass B. P., and Storzer D. 1997. Geochemistry and age of Ivory Coast tektites and microtektites. Geochimica et Cosmochimica Acta 61:1745–1772

16. Krisiuk, E.M., S.I. Tarasov, V.P. Shamov, N.I. Shalak, E.P. Lisachenko and L.G. Gomelsky, 1971. A Study on Radioactivity in Building Materials. Research Institute for Radiation Hygiene, Leningrad.

17. Shanahan, T.M., Overpeck, J.T., Peck, J., King, J., Scholz, C., Hughen, K., Drenzek, N., Beck, J.W., 2005. Paleoenvironmental changes in West Africa since the Last Glacial Maximum from a geochemical and modeling study of Lake Bosumtwi, Ghana. American Geophysical Union Fall Meeting. San Francisco.

18. Stranden, E., 1976. Some aspects on radioactivity of building materials. Phys. Norvegica, 8(3): 167.

19. Talbot, M.R., Johannessen, T., 1992. A high resolution paleoclimatic record for the last 27,000 years in tropical West Africa from the carbon and nitrogen isotopic composition of lacustrine organic matter. Earth and Planetary Science Letters 110, 23–37.

20. Turner, B.F., Gardner L.R. and Sharp, W.E. (1995): The hydrology of Lake Bosumtwi, a climatesensitive lake in Ghana, West Africa. Journal of Hydrology 183 (1996) 243-261.

21. Turner B. F., Gardner L. R., and Sharp W. E. 1996a. The hydrology of Lake Bosumtwi, a climate-sensitive lake in Ghana, West Africa. Journal of Hydrology 183:243–261.

22. Tufai, M., N. Ahmad, S.M. Mirza, N.M. Mirza and H.A. Khan, 1992. Natural radioactivity from the building materials used in Islamabad and Rawalpindi, Pakistan, Sci. Total Environ., 121: 283-291.

23. UNSCEAR, 2000. United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly, New York.

24. UNSCEAR, 1993. United Nations Scientific Committee on the Effects of Atomic Radiation. Report to the General Assembly, New York.

25. UNSCEAR, 1988. Sources, effects and risks of ionizing radiation. United Nations Scientific Committee on the effects of atomic radiation. Report to the General Assembly on the Effects of Atomic Radiation, United Nations, New York.

26. Yang,Ya-Xin, Xin-min,Wu, Zhong-ying, Jiang,Wei-xing,Wang, Ji-gen, Lu, Jun, Lin, Lei- Ming, Wang, Yuan-fu, Hsia, 2005. Radioactivity concentrations in soils of Xiazhung granite area, China. Journal of Applied Radiation and Isotopes 63, 255–259.

Table 1: Activity Concentration of 226Ra, 232Th, and 40K in the soil samples around Lake Bosumtwi

Location	Activity Concentration (Bq/kg)		
	^{226}Ra	^{232}Th	^{40}K
Pipie No. 2	26.5±0.3	108.4±9	84.9±5
Abono	4.3±0.14	4.0±1	86.8±5
Obo	7.9±0.15	4.0±1	78.6±5
Nkowi	16.9±0.2	0.7±0.2	103.3±5
Dompa	102.5± 0.5	6.9±2	288.2±9
Atafram	168.2± 0.6	13±5	340.8±12
Anyniatiase	17.5±0.26	0.9±0.2	90.9±5
Adwafo	4.2±0.14	1.6±0.3	101.9±5
Aborodwon	2.9± 0.14	1.1±0.2	20.4±3
Abease	8.7±0.15	0.9±0.2	90.1±5
Amakom	15.3±0.23	0.4±0.1	162.5±6
Duase	24.1±0.3	1.5±0.3	42.1±4
BrodeKwano	6.3±0.15	12.5±5	261.5±9
Average	31.2±0.3	11.9±4	134.8

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

Location	Absorbed Dose (nGy/h)	Effecitive Dose (mSv/y)	External Hazard Index	Radium Equivalent (Bq/kg)
Pipie No. 2	113.12	1.39	0.51	188.05
Abono	40.60	0.50	0.05	16.70
Obo	38.84	0.48	0.05	19.67
Nkowi	51.31	0.63	0.07	25.86
Dompa	171.70	2.10	0.36	134.56
Atafram	227.67	2.71	0.56	213.03
Anyniatiase	46.53	0.57	0.07	25.79
Adwafo	45.40	0.56	0.04	14.33
Aborodwon	10.51	0.13	0.02	6.04
Abease	42.13	0.52	0.05	16.92
Amakom	75.07	0.92	0.08	28.38
Duase	29.59	0.36	0.08	29.49
BrodeKwano	119.50	1.47	0.12	44.31
Average	77.8	0.9	0.15	58.70

Table 3: Comparison of ^{226}Ra, ^{232}Th and ^{40}K concentrations of soil samples around Lake Bosumtwi with that reported for other countries.

Country	^{226}Ra	^{232}Th	^{40}K	Reference
Botswana	6.1– 97.4 (34.8)	7.4–1100 (418)	335–1085.7 (432.7)	Karunakara et al (2008)
West Coast of India	5.9–77.2 (38.2)	5.9–77.2 (38.2)	14.6–344.9 (152.2)	Karunakara et al (2005)
China	40.2–442 (112)	32.6–88.1 (71.5)	440–913 (672)	Yang et al (2005)
Greece	1–238 (25)	1–193 (21)	12–1570 (360)	Anagnostakis et al. (1996)
Egypt	5-64 (17)	2-96 (18)	29-6590 (320)	UNSCEAR (2000)
Turkey	82.32–166.99 (115)	151.91–275.63 (192)	1015.48–1484.93 (1207)	Merdanoglu and Altinsoy (2006)
World Average	8–160 (32)	4–130 (40)	100–700 (420)	UNSCEAR (2000)
Ghana	2.9–168.2 (31.2)	0.4–108.4 (11.9)	20.4–134.8 (134.8)	Present Study