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Radiological study of soil, fertilizer and foodstuffs in some selected farming communities in the greater Accra region, Ghana

T.Adjirackor[1,*], E. O. Darko[1,2], G. Emi-Reynolds[1,2], D.O. Kpeglo[1,2], R. Awudu[1,2] and J. Owusu Banahene[1,2]

[1]Radiation Protection Institute, GAEC, Box LG80, Legon, Ghana.

[2]School of Nuclear and Allied Sciences, University of Ghana, Box LG 80, Legon, Ghana.

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ABSTRACT

Radioactivity concentrations of natural radionuclides, namely ^{226}Ra, ^{232}Th and ^{40}K, in fertilized and non-fertilized soils and vegetables from some agricultural areas were investigated using gamma spectrometry in order to assess the radiological implications of the extended use of phosphate fertilizers in agriculture. The mean activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in the fertilized soils were 23.84 ± 2.52 Bqkg^{-1}, 43.64 ± 2.19 Bqkg^{-1} and 199.69±3.67 Bqkg^{-1} respectively. For the non-fertilized soils, mean activity concentrations were found to be 14.01 ± 5.90 Bqkg^{-1} for ^{226}Ra, 29.40 ± 2.03 Bqkg^{-1} for ^{232}Th and 120.92 ± 4.67 Bqkg^{-1} for ^{40}K. The study has shown that fertilized soils contain slightly higher concentrations of the three radionuclides than non-fertilized soils. The measured activity concentrations of the five most frequently utilized agricultural fertilizers showed that the highest levels of ^{226}Ra (139.37±11.15kg^{-1}) and ^{232}Th (47.58±3.81 kg^{-1}) were measured in NPK 151515 and the highest level of ^{40}K (8383.47±6.70) was measured in Super master. It was also found that Sulphate of Ammonia recorded the lowest levels of ^{226}Ra, ^{232}Th and ^{40}K. The average value of $^{226}Ra_{eq}$ was 93.32 Bqkg^{-1}for fertilized soils and 63.30 Bqkg^{-1} for non- fertilized soil. The calculated mean values of the internal hazard index (H_{IN}) and external hazard index (H_{EX}) for all samples were less than unity. The average absorbed dose rate ($D_{\gamma r}$) values were 38.79 nGyh^{-1}for fertilized soil and 25.60 nGyh^{-1}for non- fertilized soils. The calculated mean annual effective dose due to ingestion of vegetables by the general public was 0.11 mSv/y for ^{226}Ra, 0.05 mSv/y for ^{232}Th and 0.62 mSv/y for ^{40} K. The result from the study indicates that radiation exposure from consumption of vegetables from the selected farming communities does not pose significant radiological hazard.

Introduction

Natural radioactivity arises mainly from the primordial radionuclides, such as ^{40}K, and the radionuclides from the ^{238}U and ^{232}Th and their decay products, which are present at trace levels in all ground formations [1]. The knowledge of concentrations and distributions of the radionuclides in these materials are of interest since it provides useful information in the monitoring of environmental radioactivity.

Gamma radiation emitted from naturally occurring radioisotopes from the ground, also called terrestrial background radiation, represents the main external source of irradiation of the human body. Natural environmental radioactivity and the associated external exposure due to gamma radiation depend primarily on the geological and geographical conditions, and appear at different levels in the soils of each region in the world [2-4].

A significant part of the total dose contribution from natural radioactivity sources comes from terrestrial gamma radionuclides [5]. Only nuclides with half-lives comparable with the age of the earth or their corresponding decay products, existing in terrestrial materials, such as ^{40}K, ^{238}U and ^{232}Th are of great interest. Abnormal occurrences of uranium and its decay products in rocks and soils and thorium in monazite sands are the main sources of high natural background radiation areas that have been identified in several locations around the world [6].

Fertilizers are chemical compounds applied to promote plant growth. Fertilizers are usually applied either through the soil (for uptake by plant roots) or by foliar feeding (for uptake through leaves). Fertilizers can also be applied to aquatic environments, notably Ocean fertilization [7].

Fertilizers can be placed into the categories of organic fertilizers composed of decayed plant/animal matter, or inorganic fertilizers composed of simple chemicals and minerals. Organic fertilizers are 'naturally' occurring compounds, such as peat, manufactured through natural processes such as composting, or naturally occurring mineral deposits; inorganic fertilizers are manufactured through chemical processes such as the Haber process, also using naturally occurring deposits, while chemically altering them e.g. concentrated triple superphosphate.

Phosphate rocks are the starting material for the production of all phosphate products and the main source of phosphorus for fertilizers. It is well known that phosphate rocks generally have enhanced concentrations of naturally occurring radionuclides. Phosphatic fertilizers are produced from rock phosphate which is known to contain elevated natural ^{238}U and its daughter products [8-10].

They mainly exist in sedimentary marine formations which also contain limestone and marine shales [10]. Therefore, phosphate fertilizers have relatively high concentrations of

Tele:
E-mail addresses: theophilonov1@yahoo.com

naturally occurring radionuclides, particularly isotopes of radium.

The concentrations of natural radionuclides in phosphate fertilizers were reviewed in the UNSCEAR report [11-12]. For a given radionuclide and type of fertilizer, the concentrations changed considerably from one country to another, depending on the origin of the components [13]. The radionuclides existing in phosphate rocks can enter the human environment through several ways such as fertilization of agricultural lands, usage of phosphogypsum in agriculture and building materials [14].

Large deposits of rock phosphate and other phosphorous compounds are found in many geographical localities. These deposits are of great economic value for the manufacture of agricultural fertilizers (superphosphates). The manufacture and use of phosphates can lead to the contamination of agricultural land during cultivation, as well as contamination of the air and water supplies. Hence, phosphates have a potential radiological health concern in addition to their chemical toxicity [15-16].

The long-continued application of phosphate fertilizers and their by-products can redistribute and elevate ^{40}K and ^{226}Ra concentrations in soils. Consequently, their presence in plants and subsequent transfer to the human food chain, mainly in acidic soils, cannot be avoided. Thus, it is important to know the proportion of such a transfer for human and animal health points of view. The most important pathway is through direct inhalation of dusts resulting in radiation doses received mainly by farmers in the farming land.

The naturally occurring radionuclides in food come mainly from natural isotopes of uranium and thorium and their daughter products and potassium. The majority of radionuclides in the environment are present as daughter products of ^{232}Th and ^{238}U, distributed by natural geological and geochemical processes, in addition to the unrelated naturally occurring ^{14}C [17]. There are many human activities which can enhance the level of naturally occurring radioactivity levels in the environment. Enhancements of naturally occurring radionuclides in the environment are made through the burning of fossil fuels and the uncontrolled mining processes [17]. As would be expected, those radionuclides accumulated in arable soil are incorporated metabolically into plants and ultimately can be transferred into the bodies of humans, including animals when contaminated foods are consumed.

With the increased public concern and awareness about radioactivity in the environment, this study has been carried out to measure the level of natural radioactivity in order to assess the radiation dose due to their ingestion in foodstuffs grown on fertilized and unfertilized soils in some selected farming communities within the Greater Accra Region.

Description of Study Area

The study area is Accra the capital of Ghana, located at the southern part of Ghana. It stretches along the Gulf of Guinea near the Atlantic Ocean covering about 170 sq Km(65 sq miles) and lies on latitude 5^0 36' 19''N (deg min sec) and longitude 0^0 13' 0''W. The City lies within the coastal- savanna zone. The almost flat and featureless Accra plain descends gradually to the gulf of Guinea from a height of 150m. The topography at the east of the city is marked by ridges and valleys, while the west is marked by low plains containing broader valleys, with round low hills with a few rocky headlands. The land is mostly flat and covered with grass and scrub, with thick patches of coconut palms along the coastlines. The annual rainfall is low; averaging 810mm is distributed over less than 80 days. The main wet seasons fall between the months of March and June and a minor rainy season around October. The mean temperature vary from 75.2 $^oF(24^oC)$ in August to $80.6^oF(27^oC)$ in March. It has a low evaluation and its soil nature is clayish and has been Ghana's capital since 1877[18].

Materials and Methods

The equipment and other materials, and the procedures used in the study are presented in this section and the mathematical models used in calculating the activity concentrations, hazard indices and the annual effective dose due to ingestion of the foodstuffs described.

Sampling and Sample Preparation

Sampling was done at seven different farms within the Greater Accra Region namely Abgobga farms, Dworwulu farm1, Dworwulu farm2, CSIR farm, Korle-bu farm, Castle farm and Mallam junction farm and was regarded as F1, F2, F3, F4, F5, F6 and F7 respectively. These sites were selected in such a way that most of them had been using fertilizer for many years in different amounts. Fertilizers were applied by means of broadcasting, so that each soil profile receives almost uniform amounts of fertilizer. The folia fertilizers were sprayed on the vegetables after three weeks. The fertilized soil of farm1 (F1), farm2 (F2), farm3 (F3), farm4 (F4), farm6 (F6) and farm7 (F7) was under regular cultivation practices have been going on for about thirty –five years while farm (F5) was over sixty-five years. F6 and F7 use compost manure without fertilizer but the rest use both.

Samples of soil and foodstuffs were randomly collected from fertilized sites from different farming communities within the Greater Accra Region. In addition, unfertilized soil samples were collected from sites distant from each of the cultivated sites in order to evaluate the impact of the application of phosphate fertilizers. The land use in the selected areas is mainly agricultural and residential. The soil texture varied gradually from approximately pure clay to pure sand. The collected samples were transferred to labeled polythene tightly closed and transferred to the laboratory for preparation and measurement. Vegetable samples were harvested from each site where available. Fertilizer samples were selected from the types that are frequently applied at the selected farming communities. Samples were prepared according to the protocol of the laboratory.

In this study a total of thirty-eight (38) samples of soil, foodstuffs and fertilizers were investigated which comprise of an average of thirteen(13) fertilized soil, seven (7) unfertilized soil, thirteen(13) foodstuffs and five(5) different types of fertilizers. For activity concentration measurement, each product was prepared into the Marinelli beakers. The beakers were closed by screw caps and plastic tape was wrapped over the caps and weighed with an electronic balance, and then stored for about four weeks prior to measurement**.** This step was necessary to ensure that radon gas is confined within the volume and that the daughters will also remain in the sample.

Measurement and Analysis of Spectra

The activity concentrations of the samples were determined by a non-destructive analysis using a computerized gamma ray spectrometry system with high purity germanium (HPGe). The relative efficiency of the detector system was 25%, and resolution of 1.8 keV at 1.33MeV of ^{60}Co. The gamma spectrometer is coupled to conventional electronics connected to a multichannel analyzer card (MCA) installed in a desk top computer. A software program called MAESTRO- 32 was used to accumulate and analyze the data manually using spread sheet (Microsoft Excel) to calculate the natural radioactivity concentrations in the sample. The detector is located inside a

cylindrical lead shield of 5 cm thickness with internal diameter of 24cm and height of 60cm. The lead shield is lined with various layers of copper, cadmium and Plexiglas, each 3mm thick. A counting time of 14hrs was used to acquire spectral data for each sample**.** The activity concentrations of the uranium-series were determined using γ-ray emissions of ^{214}Pb at 351.9 keV (35.8%) and ^{214}Bi at 609.3 keV (44.8%) for ^{226}Ra, and for the ^{232}Th-series, the emissions of ^{228}Ac at 911 keV (26.6%), ^{212}Pb at 238.6 keV (43.3%) and ^{208}Tl at 583 keV (30.1%) and 2614.7 keV (35.3%) were used. The ^{40}K activity concentration was determined directly from its emission line at 1460.8 keV (10.7%), while activities of ^{226}Ra and ^{232}Th were calculated based on the weighted mean value of their respective decay products in equilibrium

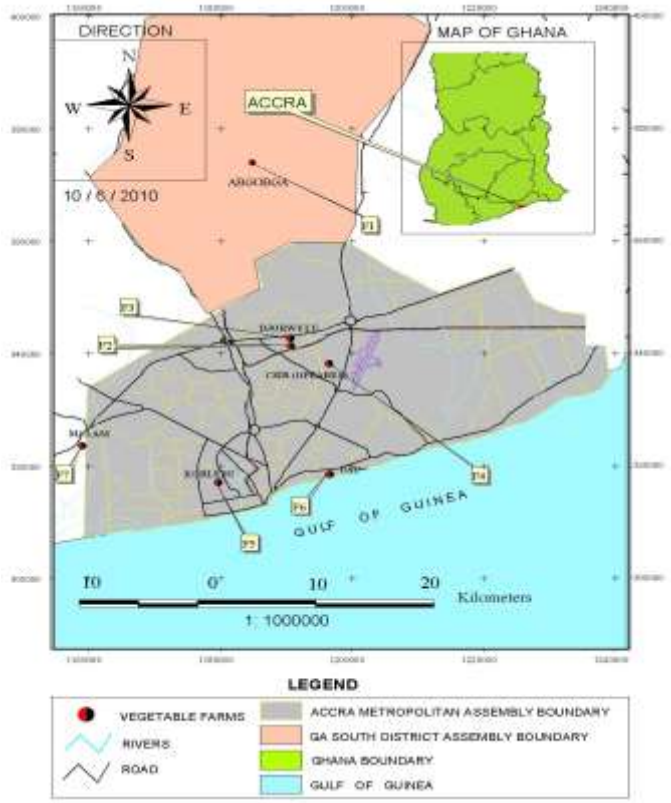

Fig 1. Map of Greater Accra showing sampling sites

The activity concentrations of the radionuclides in the samples were calculated using the expression:

$$A_{sp} = \frac{N_{sam}}{P_E.\varepsilon.T_c.M} \quad (1)$$

Where M is the mass of sample (kg), N_{sam} is the net counts for the sample in the peak range, P_E is the gamma emission probability, T_c is the counting time and ε is the photopeak efficiency

The minimum detectable activity (MDA) was calculated according to was calculated according to Currie equation [19] :

$$MDA = \frac{\sigma\sqrt{N_B}}{\varepsilon.M.P_E.T_C} \quad (2)$$

Where, MDA is in Bq/kg, σ is the statistical coverage factor equal to 1.645 at 95% confidence level, and N_B is the background counts at the region of interest of a certain radionuclide.

The weight used for MDA calculation was 0.178kg, which is weight for empty marinelli beaker

The minimum detectable activity (MDA) derived from background measurements was approximately 0.12 Bq kg^{-1}for ^{226}Ra , 0.11 Bq kg^{-1} for ^{232}Th and 0.15 Bq kg^{-1} for ^{40}K. Concentration values below these detection limits have been taken in this work to be below the minimum detection limit (MDL).

Radiation hazard assessment

In addition to the effective dose, a number of parameters were also used for the evaluation of the potential hazard associated with the natural radionuclides. These include the radium equivalent activity and the external and internal hazard indices.

Radium equivalent activity

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in materials can be compared by using the concept of radium equivalent activity ($^{226}Ra_{eq}$), which is a common radiological index used to evaluate the actual radioactivity in the materials by a single quantity. This takes into account the associated hazards. According to published reports, the Ra_{eq} is based on the estimation that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}Kproduce the same gamma-ray dose rate. Thus, the radium equivalent activity can be expressed as follows [20].

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.077C_K \quad (3)$$

Where C_{Ra}, C_{Th} and C_K are the activities (Bq/kg) of ^{226}Ra (^{238}U-series), ^{232}Th and ^{40}K, respectively. It was assumed that 370 Bq/kg of ^{226}Ra, 259 Bq/kg of ^{232}Th and 4810 Bq/kg of ^{40}K produce the same gamma-ray dose rate.

External and internal hazard indices

Assessment of the potential hazard can also be determined using the external and internal hazard indices. To limit the external gamma radiation dose to 1.0 mSv y^{-1} for the radiation hazard to be negligible, the external hazard index (H_{EX}) was used [20]. The external hazard index, H_{EX}, is used to evaluate the suitability of a material for building. The value of H_{EX} must be less than unity. The H_{EX} was calculated as:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (4)$$

In addition to the external hazard, radon and its short-lived products are also hazardous to the respiratory organs. To account for this, the maximum permissible concentration of ^{226}Ra must be reduced to half of the original activity, i.e.185 Bq kg^{-1}. The internal exposure to radon and its daughter products were quantified by the internal hazard index (H_{IN}) given by the following expression [20]:

$$H_{in} = \frac{C_{Ra}}{185} + \frac{C_{Th}}{259} + \frac{C_K}{4810} \quad (5)$$

Where C_{Ra}, C_{Th} and C_K have been defined earlier. The internal hazard index should also be less than unity in order to have negligible effect on the respiratory organs from radon and its progeny.

Absorbed dose rate

The D_γ (nGy/h) in outdoor air at 1 m above the ground was calculated by applying the dose conversion factor fromUNSCEAR 2008 report(annex B, page 327) [21] as shown below

$$D_\gamma\left(nGyh^{-1}\right) = 0.0417c_K + 0.462c_{Ra} + 0.604c_{Th} \quad (6)$$

Table 1: Measured average activity concentration of ^{226}Ra, ^{40}K, ^{232}Th in fertilized and unfertilized soil.

Farm ID	Soil Type	Average concentration in fertilized and unfertilized soil (Bq/kg)		
		^{226}Ra	^{40}K	^{232}Th
F1	Fertilized	40.74±3.25	142.24±4.39	76.66±1.63
	Non-fertilized	10.58±7.06	116.47±4.28	43.92±1.89
F2	Fertilized	20.86±3.60	98.73±4.75	35.48±2.05
	Non-fertilized	23.87±3.42	76.91±5.50	48.09±1.76
F3	Fertilized	21.13±3.91	113.26±4.96	37.99±2.00
	Non-fertilized	18.67±3.21	68.48±5.40	33.48±2.09
F4	Fertilized	10.72±5.57	80.55±4.75	20.22±2.74
	Non-fertilized	8.97±5.69	54.87±5.87	18.93±2.88
F5	Fertilized	13.54±4.61	114.23±4.11	25.39±2.53
	Non-fertilized	6.91±5.82	18.65±5.65	11.88±3.42
F6	Fertilized	12.12±5.28	245.44±2.59	32.75±2.19
	Non-fertilized	5.14±1.29	109.07±4.34	30.12±4.87
F7	Fertilized	20.88±5.24	211.05±3.57	44.59±2.08
	Non-fertilized	10.36±7.44	170.03±3.69	3.20±2.30

Table 2. Comparison of the average activity concentrations of ^{232}Th, ^{226} Ra and ^{40}K in fertilized and non-fertilized soils with published reports

Country	Sample	Activity Concentration in Bq/ Kg			Reference
		^{226}Ra	^{232}Th	^{40}K	
Yugoslavia(Vojvodina)	Fertilized	39.3	53	454	[24]
	Non-Fertilized	39.65	51.25	-	[25]
Egypt(Qena)	Fertilized	13.7±10.5	12.3±4.6	1233±646	[9]
	Non-Fertilized	11.9±6.7	10.5±6.1	6136±417	[9]
Turkey	Fertilized	55.0	26.18	-	[27]
	Non-Fertilized	36.77	24.87	-	[27]
Turkey	Fertilized	57.60	22.08	-	[28]
	Non-Fertilized	45.04	20.56	-	[28]
India	Non-Fertilized	30.60	38.2	-	[29]
Ghana	Fertilized	23.84±2.52	43.64±2.19	119.69±3.67	Present Work
	Non-Fertilized	14.01±5.90	29.40±2.03	120.92±4.67	

Table 3: Comparison of the average activity concentration of ^{232}Th, ^{226} Ra and ^{40}K in agricultural fertilizers with published reports

Country	Type of Fertilizer	Activity Concentration in Bq/ Kg			Reference
		^{226}Ra	^{232}Th	^{40}K	
Egypt	Super phosphate fertilizer	301	24	3	[7]
	Phosphate fertilizer	-	125.2-239	446.1-882.5	[30]
Egypt(Qena)	Phosphate fertilizer	366±10.5	66.7±7.3	4±2.6	[9]
Egypt	Ammonium Nitrate	0.52±0.03	-	4.96±1.04	[23]
	Ammonium Phosphate	0.32±0.20	-	4.90±1.16	
	Super phosphate	571.22±21.19	6.12±1.16	-	
	Urea	-	-	8.12±2.57	
Tanzania	Triple Super phosphate	-	444	362	[31]
	Super phosphate	-	433	491	[31]
Ghana	NPK 15 15 15	139.37±11.15	47.58±3.81	6266.65±5.01	Present Work
	Sulphate of Ammonia	1.41±0.11	15.10±1.21	42.75±3.42	
	Super Master	1.79±0.14	27.39±2.19	8383.47±6.70	
	Urea	2.81±0.22	19.92±1.59	57.34±4.58	
	Fruit Master	1.74±0.14	15.62±1.25	14522 ±11.61	

Table 4: Activity concentration of ^{226} Ra, ^{40}K and ^{232}Th (Bq/kg) in vegetable from each farm

FARM ID	SPECIES	Activity Concentration in vegetables (Bq/kg) fresh weight		
		^{226} Ra	^{40} K	^{232}Th
F1	CABBAGE	4.78± 3.82	489.70± 3.90	2.31± 18.5
	CAULIFLOWER	2.41±0.19	1735.94±1.38	0.75±0.06
	GBOMA	7.72±0.62	2755.71±2.20	4.64±0.37
F2	CHINNESE CABBAGE	7.80±0.62	848.41±6.78	5.24±0.42
	LETTUCE	6.92±0.55	1235±9.88	4.34±0.35
	RADDISH	3.26±0.26	2166.79±1.73	2.00±0.17
F3	LETTUCE	13.42±1.1	1598.24±1.27	2.88±0.23
	SWEET PEPPER	4.28±0.34	1286.99±1.02	1.50±0.13
F4	CAULIFLOWER	4.84±0.38	1713.22±1.37	3.34±0.27
F5	LETTUCE	6.15±0.49	1373.06±1.09	3.47±0.28
F6	LETTUCE	6.28±0.50	3147.95±2.51	3.74±0.30
F7	LETTUCE	9.88±0.79	1930.85±1.54	3.96±0.32
	SWEET PEPPER	4.48±0.36	1501.51±1.20	4.93±0.39
Average ± SD		6.32±2.95	1675.64±719.35	3.32 ±1.37

Table 5: Mean values of Hazard Parameters in fertilized and unfertilized soil

Farm ID	Soil type	Ra_{eq}/BqKg^{-1}	H_{EX}	H_{IN}	D_{yr}
F1	Fertilized	161.31	0.43	0.55	71.06
	Non-fertilized	82.35	0.22	0.25	36.27
F2	Fertilized	79.12	0.21	0.29	35.18
	Non-fertilized	98.56	0.27	0.33	43.28
F3	Fertilized	84.19	0.23	0.29	37.43
	Non-fertilized	71.81	0.19	0.24	31.70
F4	Fertilized	45.84	0.12	0.15	20.52
	Non-fertilized	40.27	0.11	0.13	17.86
F5	Fertilized	25.33	0.06	0.08	26.35
	Non-fertilized	58.63	0.16	0.19	11.14
F6	Fertilized	56.62	0.15	0.17	35.62
	Non-fertilized	77.85	0.21	0.24	25.12
F7	Fertilized	113.30	0.47	0.37	45.38
	Non-fertilized	28.03	0.08	0.10	13.81

Annual effective dose due to ingestion

The annual effective dose from consumption of foodstuffs containing radionuclides of ^{226}Ra, ^{232}Th and ^{40}K was calculated using the following equation given below:

$$E_{ing,\,p} = C_{p,i} H_p DF_{ing} \quad (8)$$

Where $E_{ing,\,p}$ is the annual effective dose from consumption of nuclide *i* in foodstuff *p* (Sv/a), $C_{p,i}$ is the concentration of radionuclide *i* in foodstuff *p* at the time of consumption (Bq/kg), H_p is the consumption rate for foodstuff *p* (kg/a), DF_{ing} is the dose coefficient for ingestion of radionuclide *i* (Sv/Bq). The dose conversion factors of ^{226}Ra, ^{232}Th and ^{40}K taken from the UNSCEAR report and IAEA Basic Safety Standards [21-22]

Results and Discussion

Specific Activity

In the soils of agricultural areas from where the vegetables were collected the concentrations of ^{226}Ra ,^{40}K and ^{232}Th ranged from 10.72±5.57 - 40.74±3.25 Bqkg^{-1} ,80.55± 4.75 - 245.44 ± 2.59 Bqkg^{-1} and 20.22 ± 2.74-76.66 ± 1.63 Bqkg^{-1} respectively, with an average of 23.84 ± 2.52 Bqkg^{-1}, 199.69 ± 3.67 Bqkg^{-1} and 43.64 ± 2.19 Bqkg^{-1}. For non-fertilized fields, activity concentrations of these radionuclides in the soils were found to be within 5.14±0.41–23.87 ±1.29 Bqkg^{-1} for ^{226}Ra, 18.65 ± 5.65 – 170.03 ± 3.69 Bqkg^{-1} for ^{40}K and 3.20 ± 2.30 – 48.09 ± 1.76 Bqkg^{-1}for ^{232}Th with an average of 14.01 ± 5.90 BqKg^{-1} for ^{226}Ra, 120.92 ± 4.67 BqKg^{-1} for ^{40}K and 29.40 ± 2.03 BqKg^{-1} for ^{232}Th.

When fertilized and non-fertilized soils were compared in terms of their natural radionuclide concentrations, it was found that fertilized soils contain slightly higher concentrations than non-fertilized soils as shown in Table 1 .The average activity concentration of F1-F4 which uses fertilizer in growing vegetables is 62.97Bq/kg and F5-F7 which does not use fertilizer is 61.08Bq/kg, which indicates that the application of phosphate fertilizers increases the radioactivity level of the farm soil by a certain amount. Table 2 shows the literature values for naturally occurring radionuclides in fertilized and non-fertilized soils in some studies around the world. Table 2 shows the concentrations obtained in the present study for comparison and it revealed that the activity concentration in fertilized and non-fertilized soil due ^{226}Ra, ^{232}Th and ^{40}K of the areas studied in Ghana were higher than the activity concentration of fertilized and non-fertilized soil obtained by Ahmed et al in Egypt (Qena)[9] but lower than the activity concentration of soil obtained by Bikit et al in Yugoslavia (Vojvodina)[24-25].

Activity concentration in Fertilizers

The activity concentrations ^{226}Ra and ^{232}Th and ^{40}K in the investigated fertilizers are presented in table 3. The table shows that the highest levels ^{226}Ra and ^{232}Th were detected in NPK 15 15 15 and the highest level ^{40}K was found in Super master. The lowest levels of the three radionuclides were found in Sulphate of Ammonia. Table 3 shows the literature values for naturally occurring radionuclides in fertilizers in some studies around the world for comparison and it revealed that the activity concentration of ^{40}K in Urea fertilizer used in Ghana is higher than the activity concentration of Urea fertilizer obtained by Ibrahim et al [23] in Egypt.

Activity concentration in vegetables

Activity concentrations of ^{226}Ra, ^{40}K and ^{232}Th radionuclides in frequently grown vegetables from seven different fields are presented in table 4. In the vegetables

collected from agricultural fields, the activity concentrations of ^{226}Ra, ^{40}K and ^{232}Th were found to range from 2.41±0.19Bq/kg to 13.42±1.10Bq/kg, 489.70±3.90Bq/kg to 2755.71±2.00Bq/kg and 0.75±0.06Bq/kg to 5.24±0.42Bq/kg with an average of 6.32 ± 2.95Bq/kg, 1675±719.35Bq/kg and 3.32 ±1.37Bq/kg respectively. The highest concentrations of ^{226}Ra, ^{40}K and ^{232}Th were observed in F3 Lettuce followed by F6 lettuce and F2 Chinese Cabbage while the lowest concentration of ^{226}Ra, ^{40}K and ^{232}Th were observed in F1 Cauliflower, F1 Cabbage and F1 Cauliflower respectively.

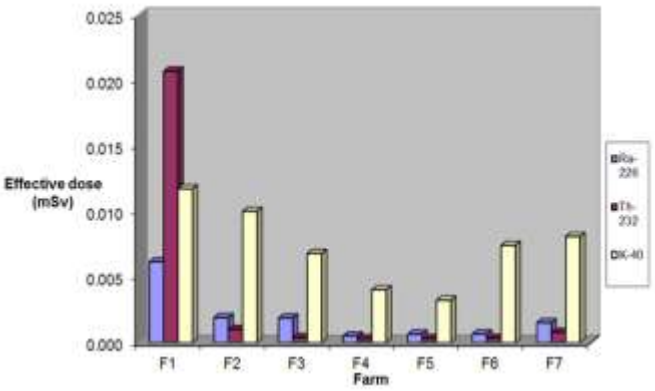

Fig 2: Annual effective dose due to ingestion of ^{226}Ra, ^{40}K and ^{232}Th in vegetables

The Activity concentrations of ^{226}Ra, ^{40}K and ^{232}Th radionuclides in vegetables in this study compared well with other work carried out around the world [5].

Hazard assessment of the soil samples

It is clear that most contribution to the total absorbed dose rate in the study areas comes from ^{238}U series, particularly ^{226}Ra radionuclide. Therefore, the radium equivalent activities (Ra_{eq}) were calculated and the results are presented in Table 5. The maximum value of Ra_{eq} must be <370 Bq kg^{-1} in order to keep the external dose <1.5 mGy y^{-1} [20,26]. As shown in table 5 the Ra_{eq} values, ranged from 25.33 to 161.31 Bq kg^{-1} with a mean value of 93.32Bq kg^{-1} for fertilized soil and 28.03 to 98.56 Bq kg^{-1} with a mean value of 63.30 for unfertilized soil which are below the recommended limit set by OECD[20,26]. In addition, Table 5 presents the values of the external and internal hazard index (H_{EX} and H_{IN}).The value of H_{EX} and H_{IN} must be lower than unity in order to keep the radiation hazard insignificant [20,26]. The maximum value of unity for H_{EX} and H_{IN} corresponds to the limit of 370 Bq kg^{-1} for Ra_{eq}. In this study the mean value for the external hazard index was 0.25 for fertilized soil and 0.18 for unfertilized soil and the mean internal hazard index was 0.32 for fertilized soil and 0.22 for unfertilized soil, which is less than unity.

Absorbed dose rate

The mean absorbed dose rate for fertilized soil and unfertilized soil as presented in Table 5 are 38.79 nGy h^{-1} and 25.60 nGy h^{-1}, respectively. These values were within the estimated average of the global terrestrial radiation of 60nGy h^{-1} [5,21].

Annual effective dose due to ingestion of vegetables

The annual intakes of vegetables due to ingestion of vegetables for ^{226}Ra, ^{232}Th and ^{40}K were determined in foodstuffs by using the formulae in equation 8. The annual intake for leafy vegetables from UNSCEAR 2008 report(annex B, page 335) of 60kg/y for Adults and the Internal Dose Conversion Factors(IDCF) of 2.8×10^{-7}SvBq^{-1} for ^{226}Ra, 2.3 × 10^{-7} SvBq^{-1} for ^{232}Th and 6.2 × 10^{-9} SvBq^{-1} for ^{40}K were used [5,22]. Figure 2 shows the effective dose due to ingestion of each radionuclide from consumption of vegetables from the selected farms, and it was found that the contributions of vegetables to the total annual committed effective dose for ^{226}Ra,^{232}Th and ^{40}K in adults are 14%, 6% and 80% respectively. It revealed that ^{40}K was the highest contributor to the annual effective dose followed by ^{226}Ra and then ^{232}Th.

The total annual committed effective doses due to ^{226}Ra, ^{232}Th and ^{40}K intakes as a result of consumption of vegetables for adults from the seven farming communities were 0.11mSv/y, 0.05mSv/y and 0.62mSv/y respectively. ^{40}K is an essential biological element distributed throughout the body and its concentration in human tissue is under metabolic (homeostatic) control. Thus the levels in humans are not normally affected by variations in the environmental levels and as a result its radiation dose within the body remains constant [10]. The doses estimated in this study could be refined if specific data on consumption rates of vegetables in Ghana were available.

Conclusion

Naturally occurring radioactive materials in soils, fertilizers and foodstuffs from some selected farming communities in the Greater Accra Region were studied for their radiological hazard. It was found that the natural radionuclides of ^{226}Ra (^{238}U series), ^{232}Th as well as ^{40}K are the main radiological constituents of soil, fertilizer and vegetable samples in the study area.

Data obtained in this research revealed that extensive application of phosphate fertilizers to soils may slightly enhance the activity concentrations of natural radionuclides. Considerable variability was evident in levels of ^{226}Ra, ^{232}Th and ^{40}K from all the farm sites and all vegetables species investigated. This could be attributed to the fact that different contaminating mechanisms may be dominant for each vegetable, namely the associated soil and the atmosphere.

The analysis revealed that the activity concentrations of the natural radionuclides in soil, fertilizers and vegetables in general are within the range of values reported in other countries apart from ^{40}K which was slightly higher.

Radiation indices ($^{226}Ra_{eq}$, H_{IN} and H_{EX}) estimated for soil to ascertain the uses of the soil as building material are generally lower than the recommended acceptable limits.

The low dose values recorded in this work suggest that, naturally occurring radioactive materials (NORMS) appears not to be an immediate problem for the vegetables consumed from these farming communities, but may require a follow up to establish long term relationship for the entire growing season following application of various types of fertilizers.

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