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Determination of radium equivalent activity from natural occurring radionuclide around a superphosphate fertilizer factory in Nigeria

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ABSTRACT

Man is continuously being exposed to radiation due to its presence everywhere on earth. This study is aimed at determining the radium equivalent activity from the soil samples collected from different locations around a superphosphate fertilizer factory in Nigeria. An efficiency and Energy calibrated high purity germanium detector was used to carry out the study while gamma vision software was used for the spectrum analysis. The Activity Concentrations of the soil samples collected from the different locations in the factory ranges from 48.99±7.47 to 520.37±20.46 BqKg^{-1} for ^{234}U, 55.32±7.59 to 215.18±8.70 BqKg^{-1} for ^{232}Th, and 101.32±13.34 to 476.04±28.07 BqKg^{-1} for ^{40}K respectively. The radium equivalent activity was found to be within the range of 215.59 to 607.29 with most of the soil samples having values less than the world allowed value for radium equivalent activity which is 370 Bq/Kg. Hence radiologically the operation of the factory does not appear to pose immediate threat to the factory workers.

Keywords: Radium Equivalent Activity, Superphosphate Fertilizer

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INTRODUCTION

Radioactivity is present everywhere and at different levels which could be due to geological and geographical conditions. There are various activities of man that could also enhance the levels of radioactivity in our environment. Human beings are exposed to radiation from sources outside their bodies; mainly, cosmic rays and gamma ray emitters in soils, building materials, water, food, and air. Studying the levels of radionuclide distribution in the environment provides essential radiological information [1]. Due to natural radioactivity in soils it has become imperative to monitor the terrestrial background radiations. Globally 80 %–90 % of mined phosphate rock is employed in the manufacture of phosphate fertilizer [2].Soils around a superphosphate fertilizer company may contain significant amount of radioactivity. Several studies worldwide have measured the activity concentration of natural radio nuclides in soil to ascertain the levels of contamination [3-10]. A number of human activities contribute to our natural radiation environment, and a number of non-nuclear industries will be due to their activities, "move" and possibly also further concentrate of some natural radioactive substances that can be found in the earth's crust [11]. The environmental impact of fertilizer production depends on the raw materials, production processes and the status of the pollution control equipment [12]. Ingesting and inhaling such levels of radio nuclides

contribute significantly to the radiation dose that people receive [13]. In addition, exposure externally to enhanced levels of radiation can elevate the health hazard risk [14]. The superphosphate fertilizer factory has fertilizer producing plants for different fertilizer production stages. The superphosphate fertilizer factory for this work is located in Kaduna North, Nigeria on latitude 7^o 24' 11'' and longitude 10^o 28' 41'' east of Greenwich meridian The data generated in this study will provide base line values of natural radioactivity in soils for that area and may be useful for authorities concern with implementation of radiation protection standards for the general population in the country, as well as to conduct further studies on this issue. This work has also helped in the development of a systematic procedure using high resolution gamma spectrometry system using gamma vision software. The objective of the present study is to determine the radium equivalent activity of natural radioactive concentration from a superphosphate fertilizer company in Nigeria. Radium equivalent activity is used to assess the hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg.

MATERIALS AND METHODS

The soil samples were collected from a super phosphate company in Nigeria. The factory is situated at the Northern side of Kaduna state, Nigeria. The geographical location was determined by an hand held GPS (Global positioning system). A total number of fourteen (14) soil samples were collected using the composite sampling method around the vicinity of the factory namely the factory gate (FG),the bagging sites (BS),the church vicinity (CHV), store house (SH), vicinity of the factory laboratory(LABV), granulation unit (GPT), phosphate rock storage house (PRV), effluent treatment unit (EFT), sulfuric acid plant (SAP), alum plant unit(APT), vicinity of the power house(PHV), acidulation unit (AD) ,clinic(CLINC),residential houses Nasarrawa behind the factory (SBF). They were all labeled appropriately. The bags samples were double bagged to prevent cross contamination of samples.

Table 1 – Sample Mass and Global Positioning System [GPS] Co-ordinates

Sample Location/Code	Mass [Kg]	Longitude	Latitude
Granulation point [GPT]	0.31042	10^o 28' 40'' N	7^o 23' 45''E
Laboratory vicinity[LABV]	0.31231	10^o 28' 47''N	7^o 24' 13''E
Sulphuric Acid plant[SAP]	0.33644	10^o 28' 43'' N	7^o 24' 15'' E
Settlement behind factory[SBF]	0.32169	10^o 28' 42''N	7^o 24' 16'' E
Acidulation[AD]	0.32493	10^o 28' 44''N	7^o 24' 18'' E
Alum plant[APT]	0.34875	10^o 28' 45''N	7^o 24' 15'' E
Store house[SH]	0.33889	10^o 28' 46'' N	7^o 24' 14'' E
Church vicinity[CHV]	0.31880	10^o 28' 41'' N	7^o 24' 13'' E
Bagging site[BS]	0.32797	10^o 28' 41'' N	7^o 24' 11'' E
Phosphate rock store[PRS]	0.33706	10^o 28' 43'' N	7^o 24' 12'' E
Power house vicinity [PHV]	0.26336	10^o 28' 40'' N	7^o 23' 59''E
Clinic[CLNC]	0.32335	10^o 28' 47''N	7^o 24' 13'' E
Factory gate [FG]	0.32283	10^o 28' 42''N	7^o 24' 14''E
Effluent treatment plant[EFT]	0.26369	10^o 28' 44''N	7^o 24' 15''E

All the samples were air-dried to avoid loss of radio nuclides [15]. The dried samples each were thoroughly grinded to ensure equal representation of samples. The samples were distinctly packed in plastic containers measuring 8.0 cm in diameter by 6.5 cm in height and width made to fit on the high purity germanium detector and labeled with codes 1, 2, 3 for each sample. The packagings in each case were triply sealed. The sealing process included smearing of the inner rims of each container lid with Vaseline jelly, filling the lid assembly gap with candle wax to block the gaps between lid and container and tight sealing lid container with masking adhesive tape. They were left for 21 days for short-lived radionuclide to allow radon and its short-lived progenies attain secular equilibrium. The activity counting was carried out using the high purity germanium detector with the gamma vision software for the computation. The system consists of a HpGe detector by Ortec Inc. connected to an Ortec series multichannel analyzer (MCA) through a preamplifier base and coupled to a personal computer. Spectrum of every sample was collected for 29,000s. Spectrum Analysis and Activity Concentration were performed using the gamma vision software. The computer was connected to an uninterrupted power supply connection (UPS) to maintain regular voltage and safeguard the data in the system. The efficiency calibration was carried out for the high purity germanium detector. The detector has a high resolution and is capable of distinguishing the gamma ray energies likely to be encountered in the measurements of the samples.

The Radium Equivalent Activity

Radium equivalent activity is used to assess the hazards associated with materials that contain ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg and is mathematically defined by [16]; [17]:

$$\mathbf{Ra_{eq}(Bq.kg{-}1) = A_{Ra} + 1.43\ A_{Th} + 0.077\ A_K}, \quad \textbf{(1)}$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively. In the above relation, it has been assumed that 10 Bq kg−1 of ^{226}Ra, 7Bq/kg of ^{232}Th and 130 Bq/kg of 40K produce equal gamma dose. The absorbed dose rates (*D*) due to gamma radiations in air at 1m above the ground surface for the uniform distribution of the naturally occurring radionuclides (^{226}Ra, ^{232}Th and ^{40}K) were calculated based on guidelines provided by UNSCEAR 2000 [18-19]. We assumed that the contributions from other naturally occurring radionuclides were insignificant.

RESULTS AND DISCUSSION

Calibrations for energy and efficiency were done with four calibration sources; Co-60,Am-241,Ra-226,Eu-152. The findings are as shown below:

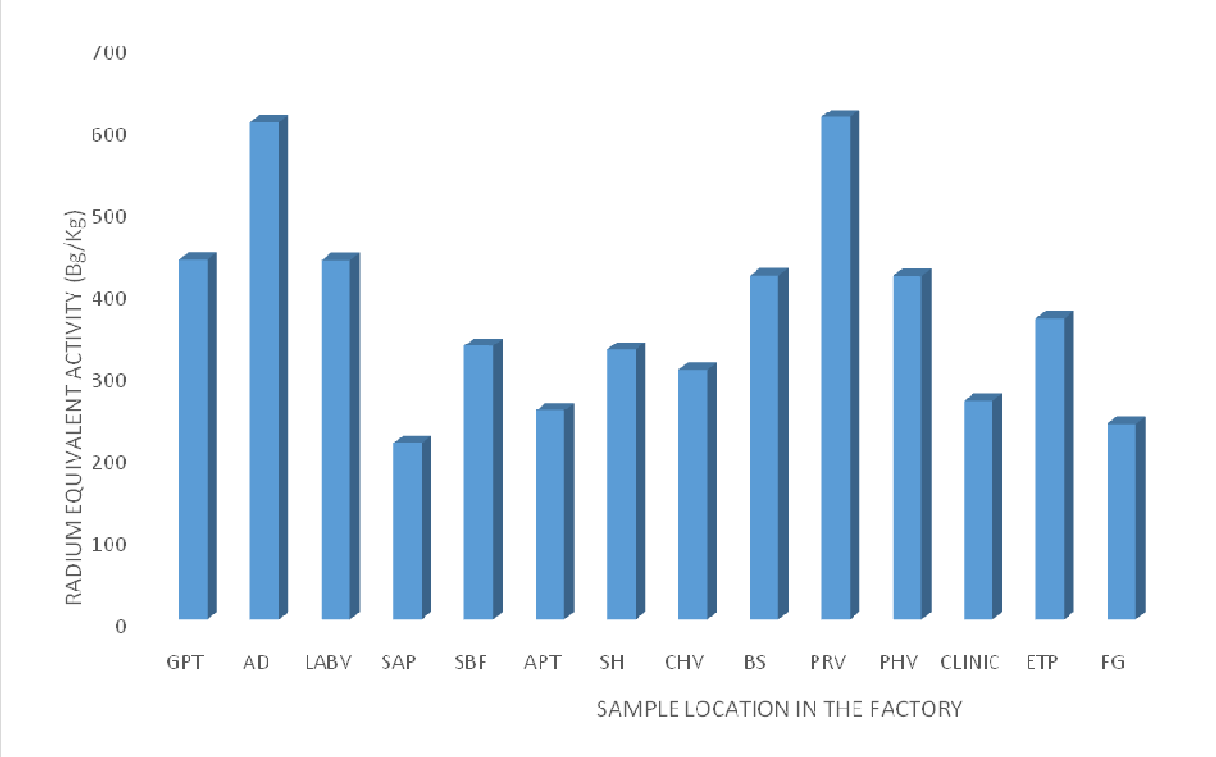

Figure 1- The Radium Equivalent Activity and their Respective Sample Locations

Table 2. Efficiency calibration results of High purity Germanium Detector

NUCLIDE	ENERGY	EFFICIENCY
Am-241	59.5	0.02
Eu-152	121.8	0.08
Ra-226	186.2	0.08
Ra-226	242	0.07
Ra-226	295	0.065
Co-60	1173.2	2.50E-02
Co-60	1332.5	2.50E-02

Table 3 Sample Locations and Calculated Radium Equivalent Activity(Ra_{eq}) using equation (1)

Sample Location	Activity Concentration (Bq/Kg ±E)		Radium equivalent Activity	
	$^{238}_{U}$	^{232}TH	^{40}K	Ra_{eq}
GPT	312.52±12.31	67.47±5.22	401.76±24.81	439.94
AD	520.37±20.46	55.32±7.59	101.32±13.34	607.29
LABV	273.96±10.72	97.04±7.59	346.73±21.26	439.43
SAP	90.95±4.09	67.37±6.62	367.50±22.40	215.59
SBF	144.28±8.17	107.58±4.63	469.30±27.78	334.23
APT	93.24±4.05	92.33±5.50	389.74±23.42	255.28
SH	201.48±8.12	69.00±7.86	384.10±23.30	329.73
CHV	103.46±4.4	117.60±7.50	432.63±25.93	304.94
BS	275.63±11.01	78.77±5.41	417.71±25.08	420.43
PRV	484.01±19.00	74.13±5.21	309.39±20.41	613.84
PHV	251.93±10.16	94.88±6.67	419.42±26.56	419.90
CLINIC	78.84±3.72	105.85±6.27	476.04±28.07	266.86
ETP	48.99±7.47	215.18±8.70	140.10±14.56	367.49
FG	95.03±8.18	79.71±3.58	389.04±23.79	238.97
Mean				375.28

Figure 1 show the radium equivalent activity which is plotted against the sample location in the bar chart above. It is observed from the bar chart of radium equivalent activity against location that the calculated radium equivalent in soils is lower than the allowed maximum value of 370 Bq/kg in eight locations and higher than the allowed maximum value at six locations (18), which includes the granulation point, acidulation point, lab vicinity, phosphate rock site, power house and the bagging site where soil samples were taken, the values of radium equivalent are much higher than the world average. But averagely the radium equivalent activity is less than the world average.

CONCLUSION

The detection of radionuclide and the radium equivalent activity in fourteen(14) soil samples from the superphosphate fertilizer company has been determined as part of radiological impact of superphosphate Fertilizer Company. However the values for the radium equivalent activity were found to be within the world average allowed maximum value of 370 Bq/kg. This study could be useful as a baseline data for radionuclide concentration and radium equivalent activity.

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