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Determination of external and internal hazard indices from natural occurring radionuclide around a superphosphate fertilizer factory in Nigeria

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ABSTRACT

Radiation is a fact of life and radioactivity in soils varies greatly. Man is being exposed to radiation continuously. This study presents result of external and Internal Hazard indices from the soils 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 internal and external hazard indices for most of the locations are greater than unity which requires radiological attention for protection.

Keywords: External and Internal radiation Hazard indices, Superphosphate Fertilizer.

INTRODUCTION

Environmental studies of radioactive concentration are very important in that it provides relevant information on radioactive levels in soil and its effects on man. Several environmental studies have being carried out around the world which serve as documented sources for radioactive levels in our environment. Radiation is present everywhere and we are continuously being exposed to radiation. Natural radioactivity is widespread in the earth environment and it exists in various geological formations such as earth crust, rocks, soils, plants, water and air [1]. Natural radioactive concentration mainly depends on geological and geographical condition and appears at different level in soils of each different geological region [2]. Soil radionuclide activity concentration is one of the main determinants of the natural background radiation. When rocks are disintegrated through natural process, radionuclides are carried to soil by rain and flow s [3]. The continuity in increasing of these radio nuclides in the environment may be attributed to several factors such as the successive utilization of phosphate fertilizer, burning of fossil fuels (crude oil and coal), mining and milling operations, and building materials. Ingesting and inhaling such levels of radio nuclides contribute significantly to the radiation dose that people receive [4]. In addition, exposure externally to enhanced levels of radiation can elevate the health hazard risk [5]. 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 meridianThe 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 external and internal hazard indices of natural radioactive concentration from a superphosphate fertilizer company in Nigeria.

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 a 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), sulpuric 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° 28' 40'' N	7° 23' 45''E
Laboratory vicinity(LABV)	0.31231	10° 28' 47''N	7° 24' 13''E
Sulphuric Acid plant(SAP)	0.33644	10° 28' 43'' N	7° 24' 15'' E
Settlement behind factory(SBF)	0.32169	10° 28' 42''N	7° 24' 16'' E
Acidulation(AD)	0.32493	10° 28' 44''N	7° 24' 18'' E
Alum plant(APT)	0.34875	10° 28' 45''N	7° 24' 15'' E
Store house(SH)	0.33889	10° 28' 46'' N	7° 24' 14'' E
Church vicinity(CHV)	0.31880	10° 28' 41'' N	7° 24' 13'' E
Bagging site(BS)	0.32797	10° 28' 41'' N	7° 24' 11'' E
Phosphate rock store(PRS)	0.33706	10° 28' 43'' N	7° 24' 12'' E
Power house vicinity(PHV)	0.26336	10° 28' 40'' N	7° 23' 59''E
Clinic(CLNC)	0.32335	10° 28' 47''N	7° 24' 13'' E
Factory gate(FG)	0.32283	10° 28' 42''N	7° 24' 14''E
Effluent treatment plant(EFT)	0.26369	10° 28' 44''N	7° 24' 15''E

All the samples were air-dried to avoid loss of radio nuclides [6]. 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 labelled 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 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 efficiency calibration was carried out for the high purity germanium detector.

External Hazard Index (Hex)

The external hazard index is a relation that quantifies the exposure factor [7].

A widely used hazard index (reflecting the external exposure) called the external hazard index Hex. The external hazard index is an evaluation of the hazard of the natural gamma radiation .it is defined as follows [8 and 9] :

$$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_K/4810) \quad (1)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively.

Internal Hazard Index (Hin)

In addition to external hazard index, radon and its short-lived products are also hazardous to the respiratory organs. The internal exposure to radon and its daughter products is quantified by the internal hazard index Hin, which is given by the equation [9 and 10]

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \quad (2)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively.

The values of the indices (H_{ex}, H_{in}) must be less than or equal to unity for the radiation hazard to be negligible.

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:

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- Calculated External Hazard Indices (Hex) using equation (1)

Sample Location	Activity Concentration (Bq/Kg ±E)			External hazard Indices
	^{238}U	^{232}TH	^{40}K	Hex
GPT	312.52±12.31	67.47±5.22	401.76±24.81	1.19
AD	520.37±20.46	55.32±7.59	101.32±13.34	1.64
LABV	273.96±10.72	97.04±7.59	346.73±21.26	1.19
SAP	90.95±4.09	67.37±6.62	367.50±22.40	0.58
SBF	144.28±8.17	107.58±4.63	469.30±27.78	0.90
APT	93.24±4.05	92.33±5.50	389.74±23.42	0.69
SH	201.48±8.12	69.00±7.86	384.10±23.30	0.89
CHV	103.46±4.42	117.60±7.50	432.63±25.93	0.82
BS	275.63±11.01	78.77±5.41	417.71±25.08	1.14
PRV	484.01±19.00	74.13±5.21	309.39±20.41	1.66
PHV	251.93±10.16	94.88±6.67	419.42±26.56	1.13
CLINIC	78.84±3.72	105.85±6.27	476.04±28.07	0.72
ETP	48.99±7.47	215.18±8.70	140.10±14.56	0.99
FG	95.03±8.18	79.71±3.58	389.04±23.79	0.65

Table 4- Calculated Internal Hazard indices (Hin) using equation (2)

Sample Location	Activity Concentration (Bq/Kg ±E)			Internal hazard Indices
	^{238}U	^{232}TH	^{40}K	H_{in}
GPT	312.52±12.31	67.47±5.22	401.76±24.81	2.03
AD	520.37±20.46	55.32±7.59	101.32±13.34	3.04
LABV	273.96±10.72	97.04±7.59	346.73±21.26	1.92
SAP	90.95±4.09	67.37±6.62	367.50±22.40	0.82
SBF	144.28±8.17	107.58±4.63	469.30±27.78	1.30
APT	93.24±4.05	92.33±5.50	389.74±23.42	0.94
SH	201.48±8.12	69.00±7.86	384.10±23.30	1.44
CHV	103.46±4.42	117.60±7.50	432.63±25.93	1.10
BS	275.63±11.01	78.77±5.41	417.71±25.08	1.88
PRV	484.01±19.00	74.13±5.21	309.39±20.41	2.96
PHV	251.93±10.16	94.88±6.67	419.42±26.56	1.63
CLINIC	78.84±3.72	105.85±6.27	476.04±28.07	0.94
ETP	48.99±7.47	215.18±8.70	140.10±14.56	1.12
FG	95.03±8.18	79.71±3.58	389.04±23.79	0.90

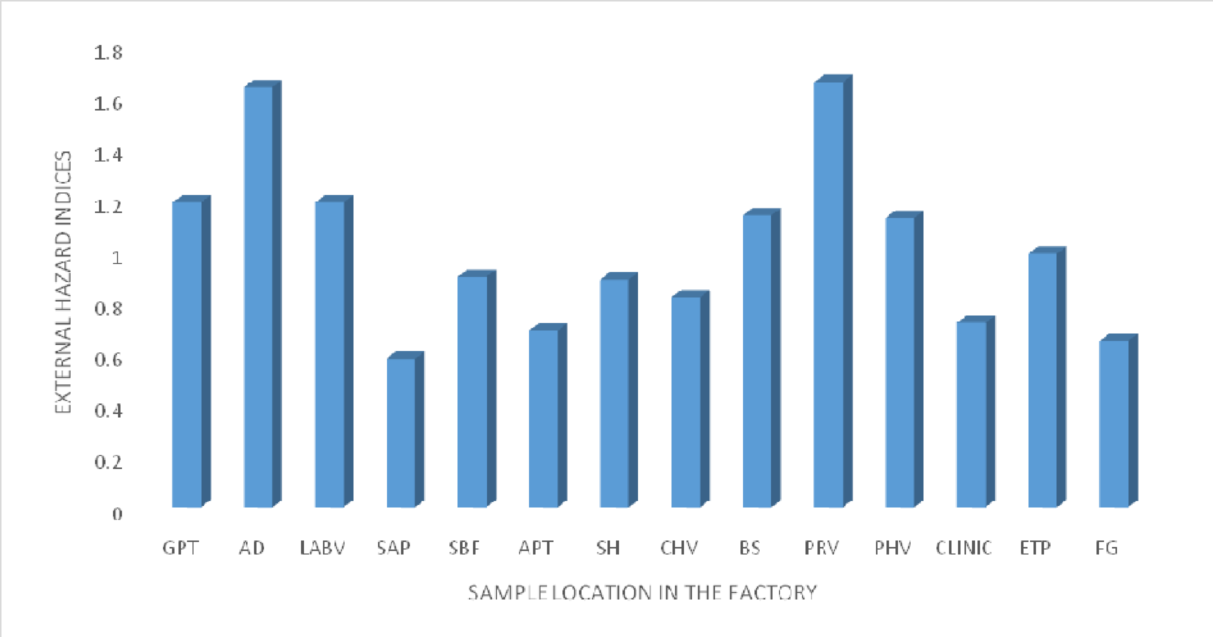

Figure 1-The External Hazard Indices around the Factory

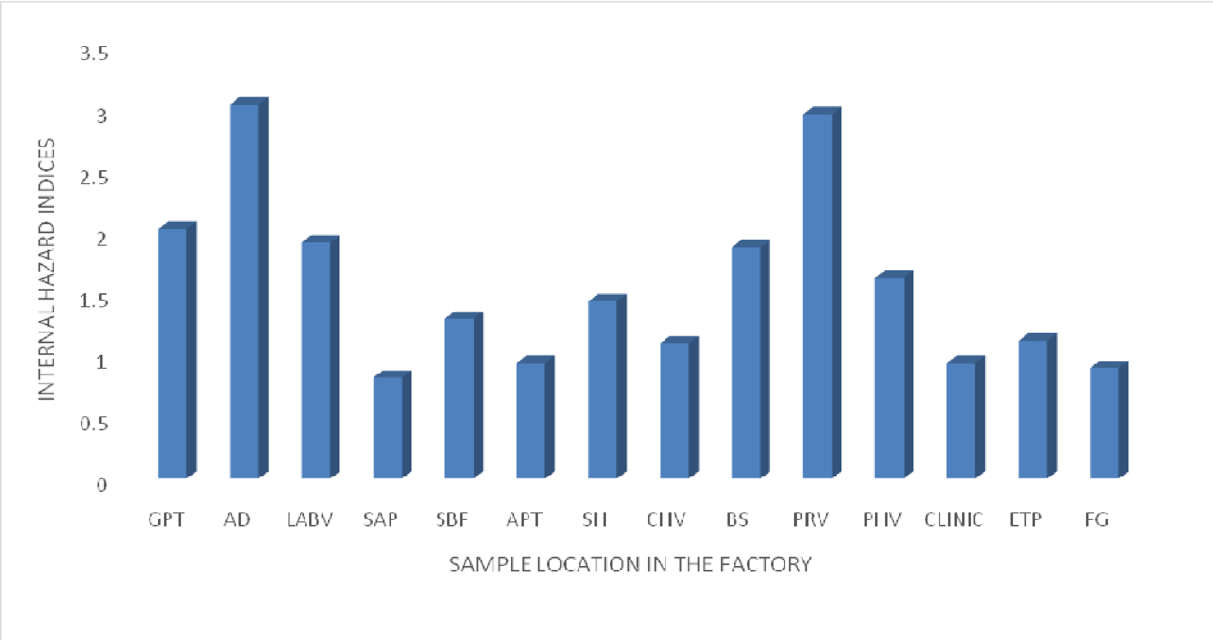

Figure 3- Internal Indices against Sample Location

The External Hazard indices for the soil samples with the exception of samples taken around the granulation point, Acidulation plant, ,Laboratory vicinity, bagging site, power house vicinity, phosphate rock vicinity were all greater than unity making the points a source of concern for safety.The result from the table 5 showing the internal hazard indices indicate that ten locations have their internal hazard indices greater than one which requires concern for radiation protection while four locations namely factory gate,clinic,alum plant,sulpuric acid plant have their values less than one.

CONCLUSION

In this work high resolution gamma spectrometry system (HpGe) detector using gamma vision software was utilized to develop a systematic procedure for internal and external hazard indices in the vicinity of a superphosphate fertilizer factory. However the external and internal hazard indices for most of the locations are greater than unity which requires a source of concern for the factory and the locations.

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