Potential Radiological Impacts of Phosphate Fertilizers Brands used in Southeast, Nigeria

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Abstract: The radionuclides present in phosphate fertilizers used in Southeast Nigeria were identified and their activity concentration determined to assess the potential radiological impact on the environment due to fertilizer applications in agricultural farm lands. The radioactivity concentration of $^{226}$Ra, $^{232}$Th and $^{40}$K in the fertilizer samples range from 13.22±1.83 to 87.37±8.98 Bq kg$^{-1}$ for $^{226}$Ra (mean: 31.71±5.4 Bq kg$^{-1}$), 0.78±0.07 to 47.65±6.05 Bq kg$^{-1}$ for $^{232}$Th (mean: 10.88±3.06) and 575.07±18.08 to 1234.80±36.61 Bq kg$^{-1}$ for $^{40}$K (mean 876.91±20.03 Bq kg$^{-1}$). The mean activity concentrations of the natural radionuclides of $^{226}$Ra and $^{232}$Th in the superphosphate fertilizer formulation were found to be above the world’s average. This will have potential health impact on humans if the fertilizers are applied in crops cultivation. The absorbed dose range from 31.01±0.03 to 75.11±0.49 nGy h$^{-1}$ (mean: 68.66±0.35 nGy h$^{-1}$). The super phosphate brand of fertilizer with the highest value of activity concentration has its value of annual effective dose as 0.08µ Sv Gyh$^{-1}$.

Keywords: Phosphate Fertilizer, Radioactivity, Radiological Impact, Nigeria

Introduction

Food is one of the cardinal needs of man. The increasing world population has become a threat to the global food security. There is, therefore, the need to increase food production to ensure food security for the growing world population. Chemical fertilizers are employed in agriculture to reclaim land and enhance crop yield (Alharbi, 2013). Chemical fertilizers are chemical compounds that provide necessary elements and nutrients to the plants (Uosif et al., 2014). Nitrogen, phosphorus and potassium are essential nutrients necessary for plant growth and therefore form major raw materials for the production of chemical fertilizer. The application of phosphate fertilizer globally for increased crop production and land reclamation has risen to more than 30 million tons annually (El-Taher and Althoyaib, 2012).

Natural radioactivity of mainly Uranium-238 ($^{238}$U), Thorium-232 ($^{232}$Th) and Potassium-40 ($^{40}$K) seen in phosphate fertilizers emanate from the phosphate ore, (due to geological reasons) which is the main raw material used for phosphate fertilizer production (UNSCEAR, 1988). Due to the presence of these radionuclides and their decay products in the phosphate ore, they are present in fertilizer products and wastes associated with it (Erdem et al., 1995; Marovic and Sencar, 1995; Uosif et al., 2014). These radionuclides are inadvertently transferred to humans through the food chain (Okeji et al., 2012). The ammonium based fertilizer brands have been shown by Uosif et al. (2014) to contain minimal amount of radioactivity and hence was not included in this study. The natural radioactivity present in phosphate fertilizers used by farmers in the five Southeastern States of Nigeria has not been established to the best of the researchers’ knowledge. There is, therefore, need for this study to estimate the possible contribution to environmental radioactivity from the application of phosphate fertilizers to farmlands in this region.

Materials and Methods

Eight different formulations of phosphate fertilizers commonly used by farmers in the Southeastern Nigeria were collected from the open market and fertilizer
warehouses in each of the five Southeastern States. They comprised seven solid and one liquid brand. Five samples each, weighing 500 gm, of the eight popular formulations were collected from the five states in the region making a total of 40 samples. National Fertilizer Company of Nigeria (NAFCON), Kaduna, manufactured four solid formulations (K₁, K₂, K₃, and K₄). Three other solid formulations were imported brands marketed by Golden investments (G₁, G₂ and G₃). A Liquid Formulation (LF) was manufactured by Green Plant International, Jos, Nigeria (Table 1). The solid samples were dried in open oven to remove moistures. The dried samples were pulverized and passed through a 2 mm sieve. Marinelli beakers designed to fit into the sodium iodide gamma spectrometer counting chamber were thoroughly washed in 0.1 m hydrochloric acid. They were then rinsed in distilled water and dried to avoid contamination. The empty beakers were weighed before the fertilizer samples were packed and hermetically sealed. The samples were weighed again to obtain the net weight of the fertilizer samples. The sealed samples were left for 28 days to allow short-lived radionuclides of ²³⁸U and ²³²Th to attain secular equilibrium.

**Gamma Spectrometric Analysis**

The activity counting was carried out using Sodium iodide (NaI) gamma-spectrometric system. The system consists of 76×76 mm NaI(Tl) detector manufactured by Canberra Inc. connected to a multichannel analyzer through a preamplifier base and interphased to an IBM personal computer. The detector has a resolution of about 8% at 662 kev for ¹³⁷Cs. This value is capable of distinguishing the gamma ray energies likely to be encountered in the measurement of the samples. Energy calibration was carried out using standard source from IAEA with photo peak of known energies in the range of 200 to 2500 keV. Efficiency calibration was achieved by NORM will be absorbed by plants and through the food chain pose radiological risk to human (Rehman et al., 2012). The absorbed does rate in air at 1m above the ground due to NORM of ²²⁶Ra, ²³²Th and ⁴⁰K were calculated based on the UNSCEAR (2000) model:

\[
D = 0.462AU + 0.604Th + 0.0417Ak
\]

where, \(A_{Ra}, A_{Th}\) and \(AK\) are the activity concentrations of ²²⁶Ra, ²³²Th and ⁴⁰K (in Bq/kg) respectively. The values of absorbed dose rate from our study range from 31.01±0.03 to 75.11±0.49 nGy⁻¹ (mean: 68.66±0.35 nGy⁻¹.) The range of values from our study is within the world’s normal range of 18-93 nGy⁻¹. However the mean value from our study was higher than the world average of 59 nGy⁻¹ (UNSCEAR, 2000). The rest of the fertilizer formulations studied had their absorbed dose rates less than the world’s average and therefore posses no radiological risk for the populations.
Table 1. Phosphate fertilizer commonly used in Southeastern Nigeria

| Code | Fertilizer Type | Formulation | Manufacturer           |
|------|-----------------|-------------|------------------------|
| K_1  | SSP             | Single super-phosphate | NAFCON                 |
| K_2  | NPK             | 20: 10: 5   | NAFCON                 |
| K_3  | NPK             | 20: 10: 10  | NAFCON                 |
| K_4  | NPK             | 20: 10: 17  | Golden investment (Imported) |
| G_1  | NPK             | 15: 15: 15  | Golden investment (Imported) |
| G_2  | NPK             | 12: 12: 17  | Golden investment (Imported) |
| G_3  | NPK             | 20: 10: 10  | Golden investment (Imported) |
| LF   | NPK             | 8% Phosphate | Green Pant, Jos         |

Table 2. Activity of radionuclide’s in the fertilizer

| Code | Activity Concentration | 232Th (Bq kg⁻¹) | 40K (Bq kg⁻¹) |
|------|------------------------|-----------------|--------------|
| K_1  | 87.37±8.98             | 47.65±6.05      | 165.62±4.98  |
| K_2  | BDL                    | 0.78±0.07       | 726.51±23.75 |
| K_3  | 17.82±2.28             | 1.72±0.08       | 1128.22±35.24|
| K_4  | 28.29±3.60             | 7.51±0.26       | 1234.26±37.33|
| G_1  | 24.23±3.12             | 11.05±0.35      | 1234.80±36.16|
| G_2  | 13.22±1.83             | 8.61±0.28       | 861.94±26.30 |
| G_3  | 19.36±2.47             | 10.81±2.86      | 575.07±18.08 |
| Range| 13.22±1.83 to 0.78±0.07| 0.78±0.07 to 575.07±18.08|
| Mean | 31.71±5.41             | 10.88±3.06      | 876.91±20.02 |

BDL: Below detection level

Table 3. Comparative mean radioactivity concentration of 226Ra, 232Th and 40K in superphosphate fertilizer samples from other countries

| Country       | Fertilizer | 226Ra (Bq kg⁻¹) | 232Th (Bq kg⁻¹) | 40K (Bq kg⁻¹) | References               |
|---------------|------------|-----------------|-----------------|--------------|--------------------------|
| Egypt         | SSP        | 336.0           | 66.70           | 4.0          | Ahmed and El-Arabi (2005) |
| Pakistan      | SSP        | 556.0           | 49.70           | 221.0        | Khater and Al-Sewaidan (2008) |
| India         | SSP        | 52.7            | 7.00            | 87.0         | Chauban et al. (2013)    |
| Saudi Arabia  | SSP        | 55.2            | 8.86            | 553.0        | El-Taher and Mohamed (2013) |
| Nigeria (Southeast) | SSP | 31.7            | 10.90           | 876.9        | Present study             |

Annual Effective Dose Rate

To estimate the annual effective dose rates, the product of absorbed dose, conversion coefficient (0.7 µSv Gy⁻¹ h⁻¹) and outdoor occupancy factor (0.2) was obtained (UNSCELAR, 2000). The annual effective dose for the superphosphate formulation was 0.08 µSv Gy⁻¹ h⁻¹. This value was the highest for all the fertilizer samples studied, of which value is less than 1µSv recommended by ICRP-60 (1990). The fertilizer samples analyzed in this study do not pose any radiological hazard to the workers and the general population.

Conclusion

The radionuclide present in the chemical fertilizers used in Southeastern Nigerian and their activity concentrations were assessed using NaI(Tl) gamma spectrometry. The mean activity concentrations of the natural radionuclides of 226Ra and 232Th in the superphosphate fertilizer formulation were found to be above the world’s average. However other phosphate fertilizer formulations studied have activity concentration of 226Ra and 232Th below the world average, but that of 40K above the world’s average, though within the normal range seen in other countries. Only the absorbed dose rate in superphosphate fertilizer was higher than the world average.

Author’s Contributions:

Kenneth K. Agwu: Participated in sample collection, coordinated the data-analysis and contributed to the writing of the manuscript.

Mark C. Okeji: Designed the research plan, participated in sample collection and all experiments, coordinated the data-analysis and contributed to the writing of the manuscript.

Paschal Tchokossa: Participated in all experiments and contributed to the writing of the manuscript.

Conflict of Interest

The author have no conflict of interest.

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