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# Estimation Of Radioactivity Content from Locally Minned Salt in Keana, Nasarawa State Nigeria

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**Abstract:** Locally mined salts that are sourced from rock and soils constitutes natural radionuclides of uranium (238U) and thorium (232Th) series, and the potassium (40K) radioactive isotope at a varying amounts. A total of 10 soil samples from different site of locally mined salt were collected and analysed using gamma ray spectrometer in order to determine the activity concentrations of the natural radionuclides. The mean activity concentrations determined for K-40, U -238, Th-232 were 1324.27 ± 68.91 Bq/kg, 147.43 ± 17.21 Bq/kg, 60.03 ± 3.56 Bq/kg which is above the worldwide weighted mean of 420 Bq/kg, 45 Bq/kg and 33 Bq/kg respectively, with the mean radium equivalent activity of 335.23 ± 27.61 Bq/kg which is below the upper limit of 370 Bq/kg, the external hazard index, the internal hazard index, the absorbed dose rate and the effective dose rate, Activity utilization index and Representative level index in the salt soil were evaluated. The results showed high gamma radiation absorbed dose and radiation hazard index, which does not present a better indications for human health in the study area.

**Keywords:** Activity Concentration, Gamma Exposure, Hazard Indices, Natural Radionuclides, Local Salt Samples.

## 1. Introduction

The study of radioactivity concentration in salts from soil provides detail information on both natural and anthropogenic sources (Masitah et al., 2008). It also creates awareness on the level of both occupational and public exposure of the study area. Radionuclides such as uranium ($^{238}$U), thorium ($^{232}$Th) and potassium ($^{40}$K) that occurs naturally undergo decay processes resulting to the emission of gamma radiation which could reach the human vicinity (Masitah et al., 2008; El-Taher, 2012). These radionuclides have different sources: they include the earth crust, rocks, soil, plants, water, sediments and air (Faweya, 2012). The presence of radionuclides that occurs naturally in our environment may results to an increase in external and internal dose received by a population and the natural radioactivity concentration depends mainly on the geological and geographical conditions that appears at varying levels in salt soil of each geological region (Jibiri, 2007; Florou, Trabidou & Nicolaou, 2007; Ibrahim, Akpa & Daniel, 2013). The human body needs about 10g of salt daily so the analysis of salt is very important (Lawal et al., 2007). The great interest expressed worldwide for the study of radionuclides that occurs naturally and environmental radioactivity has led to the performance of an in depth surveys in many countries of the world (Doaa, 2018). Naturally, radionuclide content in any consumable above the permissible threshold is term unsafe for consumption. Assessing the radionuclide content in locally mined salt is keen due to the radiological risk involves via ingestion. Salt-bearing sediments have provided great economic importance as the best and the cheapest source of NaCl that are useful both domestically and industrially (Bello, 2012). The amount of salt found in food items depend on the source and how much of those foods you are eating because of the risks associated with the consumption of salts.

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## 2. Materials And Methods

A radiological survey aimed at ascertaining the level of radionuclide content present in locally mined salt from Keana using gamma spectrometry method was carried out. The mixture of both soil and salt Samples was packaged in plastic containers with the aid of hand gloves from the mining field. Samples were grinded using agate Mortar and Pestle, and then allowed to pass through a 2.00 mm sieve while Methylated spirit and Tissue paper were used for cleansing. Global Positioning System (GPS) was used in taken the coordinates of the sampling locations. The packaged samples in polythene bag and were well labelled for easy identification. Gamma Ray Spectrometric procedure was adopted for analysis of the samples.

### 2.1 Sample Area

Keana is located in the southern region of Nasarawa state that forms a part of the low plains of the Benue origin, and volcanic cones occur around the salt mine regions of Keana and Awe. Around the salt bearing district of Keana are detached synclinal area formed by localized folding. The brine spring of Keana is associated with anticlinal axes along which salt-bearing beds within the synclines approach the surfaces. Keana salt mine is located along latitude and longitude (8° 22′ 53.0″ N, 9°20′ 06.7″ E).

### 2.2 Samples Collection

A total of ten (10) salt samples were collected from an active mining site in Keana using purposive sampling technique. The samples were collected at a distance of 10 cm apart using measuring tape and hand glove. A hand held Global Positioning System (GPS) was used to obtain the coordinates of each location.

### 2.3 Samples Preparation

Samples to be analyzed were air – dried at an ambient temperature, pulverized using agate mortar and pestle, and then sieved with a 2.00 mm mesh so as to obtain a uniform representative sample sizes. About 100 g of dry sample was weighed into a plastic container, capped, tightly sealed to avoid absorption and then labelled before it was subjected to a gamma irradiation test analysis at the National Institute of Radiation Protection and Research, university of Ibadan, Nigeria.

### 2.4 Samples Analysis

The representative samples were kept at room temperature for a minimum period of thirty-days to attain secular equilibrium. The activity concentration of three radionuclides ($^{238}$U, $^{232}$Th and $^{40}$K) of the representative samples were determined using the counting value of each gamma photo peaks, respectively. The samples were analyzed at the National institute of radiation protection and research Ibadan, Nigeria using a thallium activated 7:62X 7:62 cm, NaI (TI) detector maintained in a vertical position in a Canberra lead cylindrical shield of 10 cm thickness and 52 cm height. Each sealed sample was placed on the sodium iodide detector for the counting time of 25200 seconds.

### 2.5 Gamma Radiation Dose Assessment

The external absorbed dose rate D (nGy$^{-1}$) in air at 1.0 m above the ground level due to activity concentrations of $^{40}$K, $^{238}$U and $^{232}$Th for the ten samples were calculated using the expression (Alao & Amadi, 2012).

#### 2.5.1 Activity Concentration

$$C_A = \frac{N}{(E_A \times \gamma \times M \times t)} \quad (1)$$

$E_A$ = the efficiency of the activity of the three radionuclide, $\gamma$ = the gamma yield, M = mass of the sample, t = counting time, N = net counts, $C_A$ = activity concentration of the radionuclides.

#### 2.5.2 Absorbed Dose Rate In Air (D)

The outdoor air-absorbed dose rate *D*, in nGy/h due to terrestrial gamma rays at 1 meter above the ground level can be calculated from the activity concentration values of $^{226}$Ra, $^{232}$Th and $^{40}$K in a soil sample. It is obtained from the following (Ononugbo & Nwaka, 2017).

$$D\ (nGyh^{-1}) = (0.462C_u + 0.604C_{Th} + 0.0417C_k)\ nGyh^{-1} \quad (2)$$

#### 2.5.3 Annual Effective Dose Equivalent (AEDE/$E_d$)

The *AEDE* is the dose received by an adult given an average worldwide outdoor occupancy factor of ~ 20% (Alrefae & Nageswaran, 2013). The world average annual effective dose equivalent (AEDE) from outdoor terrestrial gamma radiation is 460 μSv/year (UNSCEAR, 2000).

$$AEDE\ (mSvy^{-1}) = D\ (nGyh^{-1}) \times 8760h \times 0.2 \times 0.7 \times 10^{-6} \quad (3)$$

### 2.5.4 Radium Equivalent Activity ($Ra_{eq}$)

$Ra_{eq}$ is an index used to assess hazards associated with materials containing $^{226}Ra$, $^{232}Th$ and $^{40}K$ nuclides. The index of radium equivalent activity is estimated on the assumption that 370 Bq/kg of $^{226}Ra$ or 260 Bq/kg of $^{232}Th$ or 4810 Bq/kg of $^{40}K$ produce the same gamma dose rate with their associated radiation hazards as presented in the equation below according to Beretka and Mathew (1995).

$$Ra_{eq}\ (Bq.kg^{-1}) = C_U + 1.43C_{Th} + 0.077C_K \quad (4)$$

### 2.5.5 Internal and External Hazard Index

The internal and external hazard indices were used to evaluate the natural gamma radiation dose rate to the populace due to radionuclides that occurs naturally in the locally mined salts study area and its purpose is to restrict the human exposure doses for terrestrial gamma-radiation to permissible dose rate equivalent limit of 1 mSv/y (Ibrahim & Mohammad, 2009).

$$H_{int} = \frac{C_k}{4810} + \frac{C_u}{185} + \frac{C_{Th}}{259} \quad (5)$$

$$H_{ext} = \frac{C_k}{4810} + \frac{C_u}{370} + \frac{C_{Th}}{259} \quad (6)$$

where $\boldsymbol{H_{int}} = Internal\ Hazard,\ \boldsymbol{H_{ext}} = External\ Hazard,$

$\boldsymbol{C_K} = Concentration\ of\ potassium;\ \boldsymbol{C_U} = Concentration\ of\ uranium;\ \boldsymbol{C_{Th}} = Concentration\ of\ Thorium$

### 2.5.6 Activity utilization index (AUI)

Activity utilization index (AUI) is evaluated using the following relationship given by Chandrasekaran *et al*. (2014) as:

$$AUI = \frac{C_U}{50} f_U + \frac{C_{Th}}{50} f_{Th} + \frac{C_K}{500} f_K \quad (7)$$

where $C_u$, $C_{Th}$, and $C_K$ are the activity concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ in $Bqkg^{-1}$ in the salt samples respectively, and $f_U$ (0.462), $f_{Th}$ (0.604), and $f_K$ (0.042) were the respective fractional contributions from the actual activities of $^{238}U$, $^{232}Th$, and $^{40}K$ to the total exposure dose rate in air.

### 2.5.7 Representative level index (RLI)

Representative level index was estimated using the expression of Alam *et al*. (1999) as follows:

$$RLI = \frac{1}{150} C_u + \frac{1}{100} C_{Th} + \frac{1}{1500} C_k \quad (8)$$

where $C_U$, $C_{Th}$, $C_K$ are the activity concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ in $Bqkg^{-1}$ respectively.

## 3 Results And Discussion

Source points for the sample identification were collected from Keana salt mining site in Keana local government area of Nasarawa state, Nigeria. At each point samples were collected, the coordinates (longitude and latitude) were recorded and is shown in table 1, the activity concentration measured in $Bqkg^{-1}$ is presented in table 2, Radium equivalent Concentration, absorbed dose rate, internal and external hazard indices and effective dose rates were presented in table 3 and the activity utilization index (AUI), representative level index for soil sample from active salt mining site in Keana were shown in table 4 while the Comparison of natural radioactivity levels in the locally mined salt samples under investigation in comparison with the world average were presented in table 5.

**Table 1: Sampling points and their respective coordinates**

| S/N | SAMPLE ID | LONGITUDE | LATITUDE |
|---|---|---|---|
| 1 | K1 | 8º9′23.0″N | 8º48′07.0″E |
| 2 | K2 | 8º9′23.5″N | 8º48′11.5″E |
| 3 | K3 | 8º9′24.0″N | 8º48′4.0″E |

| | | | |
|---|---|---|---|
| 4 | K4 | 8º9′27.2″N | 8º48′10.7″E |
| 5 | K5 | 8º9′26.0″N | 8º48′06.0″E |
| 6 | K6 | 8º9′25.8″N | 8º48′07.4″E |
| 7 | K7 | 8º9′25.4″N | 8º48′04.0″E |
| 8 | K8 | 8º9′25.4″N | 8º48′10.6″E |
| 9 | K9 | 8º9′24.5″N | 8º48′08.8″E |
| 10 | K10 | 8º9′28.4″N | 8º48′08.8″E |

**Table 2: Activity concentration of the samples measured in Bqkg$^{-1}$**

| SAMPLE ID | K-40(Bqkg$^{-1}$) | U-238(Bqkg$^{-1}$) | Th-232(Bqkg$^{-1}$) |
|---|---|---|---|
| K1 | 2017.25 ± 105.86 | 106.36 ± 13.90 | 63.09 ± 3.75 |
| K2 | 644.51 ± 33.92 | 119.53 ± 14.07 | 69.73 ± 4.15 |
| K3 | 911.28 ± 48.07 | 231.14 ± 26.35 | 17.13 ± 1.03 |
| K4 | 1536.07 ± 80.61 | 124.49 ± 16.58 | 88.69 ± 5.27 |
| K5 | 1998.07 ± 101.20 | 135.47 ± 13.21 | 70.67 ± 4.08 |
| K6 | 1454.68 ± 74.64 | 183.31 ± 19.78 | 43.09 ± 2.60 |
| K7 | 1330.88 ± 69.89 | 112.95 ± 13.99 | 66.41 ± 3.95 |
| K8 | 1090.29 ± 57.27 | 122.01 ± 15.33 | 79.21 ± 4.71 |
| K9 | 777.90 ± 40.99 | 175.34 ± 20.21 | 43.43 ±2.59 |
| K10 | 1481.81 ± 76.62 | 163.70 ± 18.71 | 58.83 ± 3.46 |
| MEAN | 1324.27 ± 68.91 | 147.43 ± 17.21 | 60.03 ±3.56 |

The activity concentrations were evaluated taking into account the mass of the sample, branching ratio of gamma decay, counting time and the efficiency of the detector as presented in table 2. The activity concentrations for the soil samples ranges from 644.51 ± 33.92 to 2017.25 ± 105.86 Bqkg$^{-1}$ for **$^{40}$K,** 106.36 ± 13.90 to 231.14 ± 26.35 Bqkg$^{-1}$ for **$^{238}$U** and17.13 ± 1.03 to 88.69 ± 5.27 Bqkg$^{-1}$ for **$^{232}$Th** respectively. The radionuclide activity concentration values are higher than the worldwide weighted mean of 33Bqkg$^{-1}$ for uranium-238, 45Bqkg$^{-1}$ for thorium, 420 Bqkg$^{-1}$ for potassium-40 (Alrefae & Nageswaran, 2013).

**Table 3: Radium equivalent Concentration absorbed dose rate, internal and external hazard indices and effective dose rates for salt samples from active mining site in Keana.**

| **SAMPLE ID** | **$Ra_{eq}$(BqKg$^{1}$)** | **$H_{ext}$(BqKg$^{-1}$)** | **$H_{int}$(BqKg$^{1}$)** | **D(nGyh$^{-1}$)** | **$E_d$(mSvy$^{-1}$)** |
|---|---|---|---|---|---|
| K1 | 351.90±27.41 | 0.95 | 1.24 | 171.36±13.10 | 0.88±0.07 |
| K2 | 268.87±22.61 | 0.72 | 1.05 | 124.21±10.42 | 0.63±0.05 |
| K3 | 325.80±31.52 | 0.88 | 1.50 | 155.13±14.80 | 0.79±0.08 |
| K4 | 369.60±30.32 | 0.99 | 1.33 | 175.13±14.20 | 0.89±0.07 |
| K5 | 390.37±26.83 | 1.05 | 1.42 | 188.59±12.79 | 0.96±0.07 |
| K6 | 356.93±29.24 | 0.96 | 1.45 | 171.35±13.82 | 0.88±0.07 |
| K7 | 310.32+26.48 | 0.84 | 1.14 | 147.80±11.76 | 0.75±0.06 |
| K8 | 319.23±26.48 | 0.86 | 1.19 | 149.7±12.32 | 0.76±0.06 |
| K9 | 297.34±27.06 | 0.80 | 1.28 | 139.67±12.61 | 0.71±0.06 |
| K10 | 361.93±29.56 | 0.97 | 1.42 | 166.79±13.93 | 0.85±0.07 |
| Mean | 335.23±27.61 | 0.90 | 1.30 | 158.97±12.98 | 0.81±0.07 |
| Range | 268.87-390.37 | 0.7-1.05 | 1.05-1.50 | 124.21-188.59 | 0.63-0.96 |

From table 3 above, the highest mean value of $Ra_{eq}$ estimated in salt soil samples is 390.37 BqKg$^{-1}$ which is significantly above the upper limit of 370 Bqkg$^{-1}$, likewise the highest mean value of both Internal and External hazard index were respectively 1.05 Bqkg$^{-1}$ and 1.50 Bqkg$^{-1}$ indicating that the values exceeded the permissible limit of unity (1). The highest value of dose rate is 188.59 nGyh$^{-1}$ which is greater than the permissible value of 55 nGyh$^{-1}$ while the peak value of the Annual effective dose equivalent of the measured samples was also above the permissible value of 460 µSv/yr (UNSCEAR, 2000).

**Table 4: Shows the activity utilization index (AUI), representative level index for salt soil samples from active mining site in Keana**

| SAMPLE ID | AUI(Bq/kg) | RLI(Bq/kg) |
|---|---|---|
| K1 | 1.91 | 2.70 |
| K2 | 2.00 | 1.92 |
| K3 | 2.42 | 2.32 |
| K4 | 2.35 | 2.74 |
| K5 | 2.27 | 2.94 |
| K6 | 2.34 | 2.62 |
| K7 | 1.96 | 2.30 |
| K8 | 2.18 | 2.33 |
| K9 | 2.21 | 2.12 |
| K10 | 2.35 | 2.68 |
| Mean | 2.20 | 2.47 |
| Range | 1.91-2.42 | |

From table 4 above, the mean value of activity utilization index estimated in salt samples is 2.20 $Bqkg^{-1}$ which is significantly above the permissible limit of unity, likewise the mean value of representative level index for the samples is 2.47 $Bqkg^{-1}$ exceeding the limit of unity (1).

**Table 5: The Comparison of natural radioactivity levels in soil samples under investigation with the world average**

| | 238U ($Bqkq^{-1}$) | 232Th ($Bqkq^{-1}$) | 40K ($Bqkq^{-1}$) | Absorbed Dose rate ($nGyh^{-1}$) | Annual Effective Dose rate ($mSvy^{-1}$) | $Ra_{eq}$ ($Bqkq^{-1}$) | $H_{ex}$ | $H_{in}$ | AUI | RLI |
|---|---|---|---|---|---|---|---|---|---|---|
| **World average values** | 33 | 45 | 420 | 60 | 1 | 370 | 1 | 1 | 1 | 1 |
| **Estimated values** | 147.43 | 60.03 | 1324.27 | 158.97 | 0.81 | 335.23 | 0.90 | 1.30 | 2.20 | 2.47 |

## 4 Conclusion

This study investigated the activity concentration, the radiological hazards in the salt samples collected from an active mining site in Keana. The findings in this study indicate that the samples have high concentrations of $^{238}U$, $^{232}Th$ and $^{40}K$ which were above the world average recommended values. The high concentration of radionuclides in the locally mined salt samples from Keana may have arise from Soil type, climatic factors and agricultural practices among other factors that have negative impacts on the human health.

**Conflict of Interest**

The authors declared that there is no conflicts of interest exist.

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