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Original Research Article

Natural Radionuclide Concentration and Its Potential Health Hazards in Common Brands of Iodized Salt Consumed in Anambra State, Nigeria

Victor Kelechi Nwodo[1], Innocent C. Ezenma[2], Michael Promise Ogolodom[3]*, Anthony Chukwuka Ugwu[1], Maryrose C. Nwodo[1], Isaiah C. Abonyi[4]

[1]Department of Radiography and Radiological Sciences, Nnamdi Azikiwe University, Awka, Nigeria
[2]FamilyCare Medical Services Providenciales, Turks and Caicos Islands
[3]Department of Radiography, Faculty of Basic Medical Sciences, Rivers State University, Port Harcourt, Nigeria
[4]Department of Environmental Health Sciences, Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria

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Abstract: ***Background***: The role of table salt (Nacl) as one of the most essential and indispensable ingredients in food cannot be overemphasized. Its usefulness in food seasoning and preservation is a common knowledge. However, its excessive consumption may pose adverse effect on human health. Being a product of our natural environment, it contains naturally occurring radionuclide material (NORMs) such as Potassium-40 (^{40}K), Radium (^{226}Ra) and Thorium-232 (^{232}Th). ***Aim***: to evaluate the Activity Concentrations and potential health Hazards associated with routine consumption of three popular brands of iodized Salt used in Anambra state, Nigerian, with emphasis on internal exposure to radiation. Salt samples were collected from major markets located within the study area. ***Materials and Methods***: The samples were prepared and analyzed for radionuclides activity concentration using a pre-calibrated 76 × 76 mm NaI (Tl) gamma spectrometry. The activity concentrations (Bq/kg) range from 97.21–125.14 for ^{40}K, 2.24–4.65 for ^{226}Ra and 7.25–12.18 for ^{232}Th. The estimated daily intake of salt among Nigerians is 5.8g per day (2118.45g/year). The total Annual Effective Dose due to ingestion range from 0.0061-0.0103 mSv per year which is lower than ICRP recommended dose of 1.0 mSv per year. Excess Lifetime Cancer Risk from Salt consumption ranges approximately between 2.36 x 10^{-5} to 3.98 x 10^{-5} which is relatively lower than the permissible value (0.29 x 10^{-3}) recommended by UNSCEAR. Consequently, the risk of developing cancer from the estimated values range from one in 42,373 to one in 25,126 persons exposed to these Salt samples over their lifetime. However, it is worthy of note that the actual risk may vary depending on other several factors such as individual susceptibility and specific radiation exposure scenarios. This finding indicates that consumption of these Salt products does not pose significant Radiological Health hazard to the population.

Keywords: Radionuclide Concentration, Radiological Health Hazard, Salt.

INTRODUCTION

Radionuclide otherwise known as radioactive nuclide refers to an unstable form of a chemical element that spontaneously decays, resulting in the emission of nuclear radiation. This process of nuclear disintegration is called radioactivity [1], and the excess energy generated by this process can be used in one of three ways: emitted from the nucleus as gamma radiation; transferred to one of its electrons to release it as a conversion electron; or used to create and emit a new particle (alpha or beta) from the nucleus. During these processes, the radionuclide is said to undergo radioactive decay. These emissions are considered ionizing radiation [2, 3]. Ionizing radiation has sufficient energy to remove electrons from atoms or molecules, causing structural and functional changes in biological tissues. On the other hand non-ionizing radiation lacks this ability but can induce molecular vibrations and heat. Radionuclides occur naturally or are artificially produced in nuclear

***Corresponding Author:** Dr. Michael Promise Ogolodom
Department of Radiography, Faculty of Basic Medical Sciences, Rivers State University, Port Harcourt, Nigeria

reactors, cyclotrons, particle accelerators or radionuclide generators [4].

Natural sources of ionizing radiation include cosmogenic radionuclides formed by cosmic ray interactions and primordial radionuclides such as Uranium, Thorium, and Potassium-40 that have been present since the Earth's formation [5]. Artificial sources arise from activities such as nuclear weapons testing and nuclear accidents, introducing fallout radionuclides like ^{137}Cs, which can bioaccumulate and pose both radiological and toxicological risks [6].

Salt (NaCl) is an essential dietary component for humans, animals, and plants, playing a critical role in electrolyte balance, nerve conduction, and cellular metabolism. It can be sourced from seawater and mineral deposits and is also used extensively in various industries [7]. The human body requires approximately 10 g of salt daily. However in Nigeria, estimated daily intake of salt is 5.8g per day (2118.45g/year), making its quality and safety a public health priority. Contamination of salt with radionuclides increases the internal body burden of radiation, thereby elevating long-term health risks [8-10].

Human exposure to ionizing radiation occurs through three primary pathways: external exposure to gamma rays, inhalation of airborne radionuclides such as radon, and ingestion of contaminated food and water. In foodstuffs, ^{40}K is typically the most significant naturally occurring radionuclide, with Uranium and Thorium decay products usually present in trace amounts [11, 5]. Chronic exposure to low levels of radiation may not produce immediate health effects but contributes incrementally to cancer risk and other long-term conditions such as cardiovascular disease [12, 13].

Previous studies have quantified radionuclide levels in salt and estimated associated radiation doses and hazards in other climes. For example, Kansaana *et al*., [8], reported activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Ghanaian salt samples, with corresponding annual effective doses well below the World Health Organization's recommended limit of 1 mSv/year. However, naturally occurring radioactive materials (NORM) are present in all salts, and their levels vary geographically and geologically.

Anambra is the major commercial and industrial city in South-eastern Nigeria with high population density. As a result, residents consume varieties of iodinated Salt brands for domestic and industrial purposes. Despite the potential for radionuclide contamination, there is paucity of local data on the Radiological quality and assay of salts consumed in this region. In Nigeria generally, the National Agency for Food and Drug Administration and Control (NAFDAC) has formulated and enforced safety standards for different consumed products such as water. However, these standards only emphasize the physico-chemical and microbial parameters which are non-radioactive contaminants at the expense of radionuclide activity concentration limit [16].

Assessment of activity concentrations of ^{40}K, ^{226}Ra and ^{232}Th in these samples of Salts therefore became imperative in order to evaluate the fraction of annual committed effective dose received by residents of Anambra, through salt intake.

MATERIALS AND METHODS

Area and Design of the Study

A prospective cross-sectional spectrometric study was conducted in Anambra State, located in the South-Eastern part of Nigeria with gps coordinates of 6° 13' 15.239'' N and 6° 56' 13.041 E.

Sample Collection and Preparation

The salt samples were collected from major markets and supermarkets within the study area and then transported to Center for Energy Research and Training (CERT), Ahmadu Bello University Zaria for analysis. In the laboratory, the samples were dried at a temperature of 105° for 24hrs to obtain dry mass with constant weight. It was then crushed, and sieved with a fraction of 2mm to attain homogeneity. The samples were packaged in radon-impermeable cylindrical containers (7.6 cm × 7.6 cm) and were triple-sealed with Vaseline, candle wax and adhesive tape to prevent radon escape. The sealed samples were allowed to reach circular equilibrium by storing them for 30 days before counting.

Gamma Spectrometric Analysis

The analysis of the sampled salt brands was performed at the Centre for Energy Research and Training (CERT), Zaria, Nigeria. The gamma ray spectrometer used has an extended range electrode germanium detector with a model number GEM-30195. It has a relative efficiency of 43.4% of full width at half maximum (FWHM) of 1.80 keV and amplifier constant of 6µs. It is connected to a computerized MCA where gamma spectrum analysis is performed using the MAESTRO emulation software program. A pre-calibrated 76 × 76 mm NaI (Tl) detector coupled to a photomultiplier tube and shielded with lead, cadmium and copper was employed. Calibration was done using Cs-137 and Co-60 sources and IAEA reference standards RGK-1, RGU-1 and RGTh-1 were used for ^{40}K, ^{226}Ra and ^{232}Th respectively.

Activity concentrations (Bq/kg) were calculated after subtracting background counts from sample spectra. The activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in the salt samples were determined by the quantitative analysis of the spectra acquired from the gamma-ray spectrometry using gamma-ray spectrum analysis software. The activity concentration (C) in Bq/Kg of each natural radionuclides in the samples were calculated after decay correction according ICRP using.

$$Cs = \frac{Ca}{Ey \times Ms \times tc \times Py} \qquad \text{Eq......1}$$

Where Cs is the sample activity concentration, Ca = net peak area, Ey = Efficiency of the detector for y energy intensity, Ms = Sample mass, tc = total counting time, Py = The abundance of the y line in a radionuclide.

Annual Effective Dose

For the assessment of human internal exposure to ionizing radiation from oral absorption of specific radionuclides, the annual effective dose due to ingestion is determined according Cardidi *et al.*, [6], from the equation.

$$D_{ing} (= A_C . I_R . D_F \qquad \text{Eq......2}$$

Where D (Sv/y) = Annual effective dose for food ingestion.

AC (Bq/Kg) = Activity concentration of radionuclides in the ingested food.

IR (Kg/y) = Annual intake of salt

DF (Sv/Bq) = Dose conversion coefficient.

The conversion coefficients DF (Kg/year) for natural radioactive isotopes of ^{226}Ra, ^{232}Th and ^{40}K are 2.8x10-7, 2.3x10-7 and 6.2x10-9 respectively for adults greater 17 years of age. This is used to evaluate human health hazards arising from ingestion of salt samples for the age categories above 17 years. Those below 17 years were not included because salt consumption is not recommended for babies under 24 months and the intake of those from 24 months to 17 years depends on the child's need.

Excess Lifetime Cancer Risk (ELCR)

This is used to assess the probability of developing cancer over a person's lifetime beyond the natural background rate. It helps to quantify and compare potential health burden associated with the consumption of different brands of sampled salts. It is calculated from the following equation according to EPA [18].

$$ELCR = A_{ir} \times A_{ls} \times R_c \qquad \text{Eq..................3}$$

Where A_{ir} (mSv/year) is the annual intake of radionuclide, A_{ls} is the mean life span and is equal to 70 years and R_C (Sv^{-1}) is the mortality cancer risk factor for ingestion of food (S^{-1}) per Sievert. The ingestion cancer risk factor in Bq^{-1} for ^{226}Ra, ^{232}Th and ^{40}K are 9.56×10^{-9}, 2.45×10^{-9} and 5.89×10^{-10} respectively.

Method of Data Analysis

Data were analyzed using Microsoft Excel, applying descriptive statistics such as mean and standard deviation and the results were compared with UNSCEAR safety limits. Annual committed Effective dose and Excess Lifetime Cancer risks were also calculated.

Table 1: Activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in three salt Brands

Brands of Salt	^{40}K ± Error (B/Kg)	^{226}Ra ± Error (Bq/Kg)	^{232}Th (B/Kg)
Uncle Palm	97.21 ± 12.64	4.65 ± 0.432	7.25 ± 1.42
Mr. Chef	104.63 ± 9.63	2.24 ± 0.208	8.60 ± 1.68
Dangote	125.14 ± 11.51	3.28 ± 0.305	12.18 ± 2.39

Keys: ^{40}K = Potassium-40, ^{226}Ra = Radium-226, ^{232}Th = Thorium-232, B/Kg =Becquerel per Kilogram.

Table 2: Annual committed effective dose from range of activity concentrations from ^{40}K, ^{226}Ra and ^{232}Th in salt brands

Salt Brands	^{40}K (mSv)	^{226}Ra (mSv)	^{232}Th (mSv)
Uncle Palm	0.0011-0.0014	0.0025-0.0030	0.0059-0.0083
Mr. Chef	0.0012-0.0015	0.0012-0.0015	0.0034-0.0050
Dangote	0.0015-0.0018	0.0017-0.0021	0.0048-0.0071

Result and Discussion

Table 1 above also shows that the activity concentration of Radium (^{226}Ra) is highest in Uncle Palm (4.65 ± 0.432 Bq/Kg) and lowest in Mr. Chef (2.24 ± 0.208 Bq/Kg) with Dangote salt sample in-between. They are higher than the non-detectable levels reported by Baloch *et al*., [14], in Pakistan but lower than the value (15.9 Bq/kg) reported in a more recent study in Iran (15). Variations in geographical origin, production processes and environmental exposure probably accounts for these differences. All estimated values are found to be well below the UNSCEAR (2000) limit of 400 Bq/kg.

The specific activity concentration of thorium (^{232}Th) in Dangote salts (12.18 ± 2.39 Bq/Kg) is highest and lowest in Uncle Palm salts (7.25 ± 1.42 Bq/Kg) with Mr. Chef salt having a value in- between as shown in table 1. While this is above detection levels as reported in Khewra salt mines [14], these values are slightly lower than those found by Alshebly *et al.,* [15], in Iranian market salts. Geographic and environmental differences may explain the observed variations. All values were below the UNSCEAR (2000) safety limit.

The specific activity concentration of each of the radionuclides contained in each brand of the salt samples as calculated from equation 1 above is displayed in table 1. Potassium (^{40}K) appears to be highest in Dangote (125.14 ± 11.51 Bq/Kg) and lowest in Uncle Palm (97.21 ± 12.64 Bq/Kg) with Mr. Chef having a value that is in-between as shown in table 2.

These values are higher than those reported by Baloch *et al*., where the mean concentration was 36 ± 20 Bq/kg [14]. The differences may be attributed to geological and geographical factors in the areas were the raw materials for the samples in this present research were sourced. Nevertheless, all values remain below the UNSCEAR (2000) recommended limit of 400 Bq/kg, indicating radiological safety.

Total annual effective dose due to ingestion of salt samples range from 0.0061-0.0103 mSv per annum as calculated by equation 2, and displayed in table 2, above. The Annual Effective Dose from all the salt samples analyzed ranges from 0.0061-0.0103 mSv per year. This is however lower than the annual advisory dose limit of 1.0 mSv per year as recommended by ICRP for radionuclides in food.

The human body requires approximately 10 g of salt intake daily. However in Nigeria, estimated daily intake of salt is 5.8g per day (2118.45g/year). Estimated Lifetime Cancer Risk range from 2.36x 10^{-5} to 3.98x 10^{-5} which is relatively low compared to the annual permissible value of (0.29 x 10^{-3}) as recommended by UNSCEAR [8-10]. Consequently the risk of developing cancer from these values is estimated to be between one in 42,373 to one in 25,126 persons exposed to these Salt samples over their lifetime. However, it is essential to consider the broad context of overall exposure to radiation from all sources rather than just this specific salt consumption.

Conclusion

The radioactivity concentration of ^{226}Ra, ^{232}Th, ^{40}K and their activity concentrations in Salts brands commonly consumed in Anambra state, Nigeria were determined in this study. It was found that the radiation dose due to consumption of salt was less than the annual advisory dose limit, and poses no threat to public health. The Excess lifetime cancer risks (ELCR) attributable to consumption of the three brands of sampled salt were also found to be less than the acceptable world average value.

Conflict of Interest: None declared among the authors

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