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Exposure to Naturally Occurring Radioactive Potassium-40: Concerns for Nigeria

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Abstract: **Potassium-40 (K-40) is a naturally occurring radioactive isotope that contributes to environmental radiation exposure. As an essential element in biological systems, K-40 is present in soil, water, food, and human tissues, making exposure unavoidable. However, the radiological impact of K-40, particularly in Nigeria, has not been thoroughly studied. This review examines the sources, distribution, and health implications of K-40 exposure in Nigeria, taking into account dietary intake, environmental factors, and occupational exposure. It evaluates existing studies on radiological assessments in the country and highlights gaps in regulatory frameworks for radiation protection. The paper also discusses potential health risks, including internal radiation dose implications, and suggests strategies for improving monitoring and public awareness. Strengthening radiation safety regulations and conducting further research on K-40 exposure pathways are essential for effective risk management.**

Keywords: **Potassium-40, Natural Radioactivity, Environmental Exposure, Radiological Impact, Nigeria.**

1. INTRODUCTION

Natural radioactivity primarily comes from primordial radionuclides, such as potassium-40 (K-40), and the decay series of uranium-238 (U-238) and thorium-232 (Th-232). These radionuclides are generally present at trace levels (Abdel-Mageed et al., 2010).

Potassium-40 (K-40) is a naturally occurring radioactive isotope of potassium, an essential nutrient for humans, animals, and plants. Given its widespread presence in the environment, K-40 plays a significant role in background radiation exposure. While global studies have extensively documented its natural occurrence and effects, there is a lack of literature specifically addressing its impact in Nigeria. This review aims to evaluate K-40 exposure pathways in Nigeria, its potential health risks, and the regulatory measures in place to mitigate its effects.

Studies and surveys of natural environmental radiation, which constitute the main source of human exposure, are crucial for health physics. Therefore, evaluating the natural radiation background is necessary to detect contamination among the population and the environment. Research on radiation levels and radionuclide distribution in the environment provides essential radiological baseline information. This information is vital for understanding human exposure to both natural and man-made sources of radiation and is necessary for establishing rules and regulations related to radiation protection (Harb et al., 2008).

To estimate a lifetime cancer mortality risk, if it is assumed that 100,000 people were continuously exposed to a thick layer of soil with an initial average concentration of 1 pCi/g potassium-40, then 4 of these 100,000 people would be predicted to incur fatal cancer over their lifetime (Peterson, *et al.,* 2007).

Potassium is the seventh most abundant element in the Earth's crust and the sixth most abundant element dissolved in the oceans (Peterson et al., 2007). The radioactive isotope potassium-40 comprises 0.017% of naturally occurring potassium, while potassium-39 makes up 93%, and the remainder consists of potassium-41. The particle composition of potassium isotopes is presented in Figure 1. To become stable, potassium-40 undergoes beta decay to form the daughter isotopes Ca-40 or Ar-40, as presented in Figure 2.

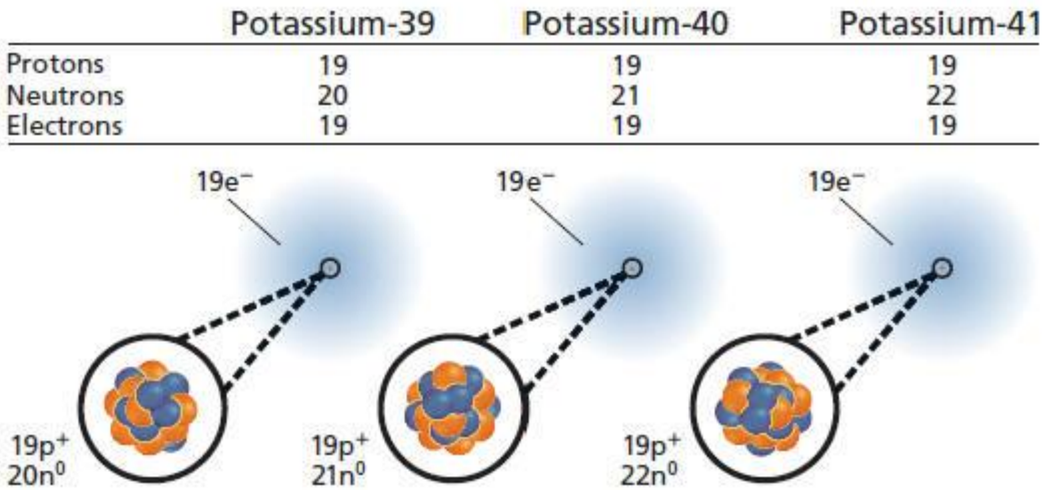

Figure 1: Particle composition of K-Isotopes

Potassium-40 (K-40) undergoes negatron decay to form Carbon-40 (C-40), which then becomes stable by emitting two positrons and transmuting them into Argon-40 (Ar-40) 80% of the time. Alternatively, K-40 can also transmute to Ar-40 by emitting a single positron. This occurs approximately 10 times in every 100 decays.

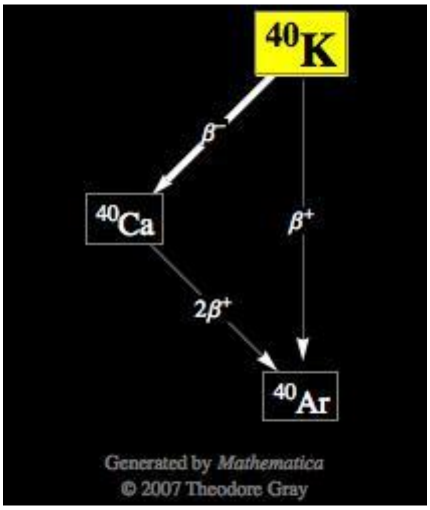

Figure 2: Transmutation of K-40 to Ar-40

The energy released in this process as well as the probability of occurrence is summarized in Table 1.

Table 1: Data for transmutation of K-40

Probability	Mode	Decay Energy	Daughter
89.28%	β^-	1311.07keV	^{40}Ca
10.72%	β^+	482.491keV	^{40}Ar

(periodictable.com)

The half-life of potassium-40 is 1.3 billion years. It decays into calcium-40 by emitting a beta particle, which occurs 89% of the time, without producing any gamma radiation. In contrast, it decays into argon-40 through electron capture, releasing an energetic gamma ray 11% of the time. Potassium-40 is a significant radionuclide because it contributes to the dose from naturally occurring radiation. The radioactivity from the potassium-40 in our bodies accounts for about half of our annual exposure to all radiation sources. Like all radionuclide elements, potassium-40 can increase the risk of cancer through inhalation and ingestion.

Environmental Presence of K-40

Potassium is found in the Earth's crust, oceans, and all organic materials. Its concentration in the Earth's crust is approximately 15,000 milligrams per kilogram (mg/kg), which is about 1.5%. In seawater, the concentration of potassium is around 416 milligrams per liter (mg/L). Naturally occurring potassium-40 makes up about 0.012% of total potassium, resulting in a concentration of approximately 1.8 mg/kg in the Earth's crust, which is equivalent to about 13 picocuries per gram (pCi/g).

Sources and Distribution of K-40 in Nigeria

K-40 is widely distributed in nature, occurring in rocks, soil, and water. In Nigeria, major sources of exposure include:

1. **Geological Formation**: Nigeria's diverse geological landscape, particularly in regions with granite, laterite, and sedimentary deposits, contributes to variations in K-40 concentrations.
2. **Food and Water Intake**: Dietary sources such as tubers, cereals, and vegetables naturally contain potassium, leading to internal exposure to K-40.
3. **Industrial and Occupational Exposure**: Workers in mining, fertilizer production, and oil and gas industries may experience elevated exposure levels due to the handling of materials with high potassium content.

Potassium has a strong affinity for binding to soil, with concentrations in sandy soil particles estimated to be 15 times higher than those in interstitial water (the water found in the pore spaces between soil particles). It binds even more tightly to loam and clay soils, resulting in concentration ratios exceeding 50. Along with nitrogen and phosphorus, potassium is a key component of soil fertilizers, and its levels in soils are significantly affected by fertilizer use. It is estimated that approximately 3,000 curies (Ci) of potassium-40 are added to U.S. soils each year.

Potassium-40 behaves in the environment similarly to other potassium isotopes, being incorporated into the tissues of all plants and animals through normal biological processes. It is the predominant radioactive component found in human tissues and in most food sources. For instance, milk contains about 2,000 picocuries per liter (pCi/L) of natural potassium-40 (Peterson et al., 2007).

Health Issues associated with consumption of K-40

Potassium-40 can be taken into the body via water, food, or inhalation. Once taken in, potassium-40 behaves in the body in the same manner as other potassium isotopes. Humans require potassium to sustain biological processes, with most (including potassium-40) being almost completely absorbed upon ingestion, moving quickly from the gastrointestinal tract to the bloodstream.

K-40 emits both beta and gamma radiation, which can lead to external and internal exposure. While the human body regulates potassium levels to maintain homeostasis, prolonged exposure to elevated levels of K-40 may have several effects:

1. Internal Radiation Dose: Ingesting foods rich in K-40 results in a continuous, albeit low, internal radiation dose.
2. Cellular and DNA Damage: While K-40 exposure is generally considered low-risk, excessive accumulation may increase the risk of mutations and carcinogenesis.
3. Occupational Health Risks: Workers in industries with high potassium exposure may experience slightly elevated radiation exposure, highlighting the need for protective measures.

Potassium 40 and Body Chemistry

The potassium-40 that enters the bloodstream after ingestion or inhalation is quickly distributed to all organs and tissues. Potassium-40 is eliminated from the body with a biological half-life of 30 days.

The potassium levels in the body are tightly regulated through homeostasis, meaning the body actively manages the amount of potassium retained to maintain the normal range necessary for proper functioning. These levels are not affected by changes in external environmental conditions.

The potassium-40 content in the human body remains constant, with an adult male containing approximately 0.1 microcuries, equivalent to 100,000 picocuries (pCi). Each year, this isotope contributes an estimated dose of about 18 milligrams (mrem) to the soft tissues and 14 mrem to the bones. Potassium-40 poses both external and internal health risks.

The strong gamma radiation associated with the electron-capture decay process (which occurs 11% of the time) makes external exposure to this isotope a concern. While in the body, potassium-40 poses a health hazard from both the beta particles and gamma rays. Potassium-40 behaves the same as ordinary potassium, both in the environment and within the human body – it is an essential element for both. Hence, what is taken in is readily absorbed into the bloodstream and distributed throughout the body, with homeostatic controls regulating how much is retained or cleared. The health hazard of potassium-40 is associated with cell damage caused by the ionizing radiation that results from radioactive decay. While ingestion is generally the most common type of exposure, the risk coefficients for this route are lower than those for inhalation. As for other radionuclides, the risk coefficient for tap water is about 70% of that for dietary ingestion. In addition to risks from internal exposures, an external gamma exposure risk also exists for potassium-40.

Research and Regulatory Gaps in Nigeria

There is a lack of comprehensive data on K-40 exposure levels across different regions of Nigeria. Studies conducted in select areas indicate varying concentrations in soil and food sources, but a nationwide radiological assessment is absent. Additionally, regulatory frameworks for radiation protection primarily focus on artificial sources, such as medical and industrial radiation, with limited emphasis on natural radioactivity.

Exposure activity Proportion of Naturally Occurring K-40: focus on Nigeria

Data for mean values of a wide range of samples analyzed for NORMS were evaluated for the percentage composition of K-40 radionuclide. The reviewed literature is based on an analysis of over 1000 environmental samples investigated for activity concentration. The sampling geology covered some 18 countries at random as presented in Table 2.

Table 2: NORMs radionuclide concentration for selected countries

Country	Ra-226	Th-232	K-40	%K	Reference
Australia	51.8	48.1	114.7	53.44827586	Beretka and mathew (1985)
Austria	26.7	14.2	210	83.69868473	Sorantin and Steger(1984)
Bangladesh	61	80	1133	88.93249608	Roy et al. (2005)
Brazil	61.7	58.5	564	82.43203742	Malanca et al. (1993)
China	51.7	32	207.7	71.27659574	Lu et al. (2012)
Egypt	35	19	93	63.26530612	Elbahi, (2004)
Finland	40.2	19.9	251	80.68145291	Mustonen (1984)
Greece	92	31	310	71.59353349	Stoulos et al., (2003)
Italy	46	42	316	78.21782178	Sciocchetti et al. (1984)
Japan	36	21	139	70.91836735	Suzuki et al. (2000)
Malaysia	81.4	59.2	203.5	59.13978495	Chong and Ahmed (1982)
Netherlands	27	19	230	83.33333333	Ackers et al., (1985)
Norway	29.6	18.5	259	84.3373494	Stranden and Bertiez, (1980)
Pakistan	26.1	28.7	272.9	83.27738785	Khan and Khan (2001)
Turkey	41	26	267	79.94011976	Turhan, (2008)
Nigeria	43.8	21.5	71.7	52.33576642	Ademola, (2008)
Ghana	35.94	25.44	251	80.35085473	Kpeglo et al., (2011)
Algeria	41	27	422	86.12244898	Amrani and Tahtat, (2001)

The review aims to assess the risk of K-40 exposure among the Nigerian population. The results are further evaluated to compare Nigeria's exposure levels with those of 17 other countries. Trends in exposure to this specific radionuclide are illustrated in Figure 3.

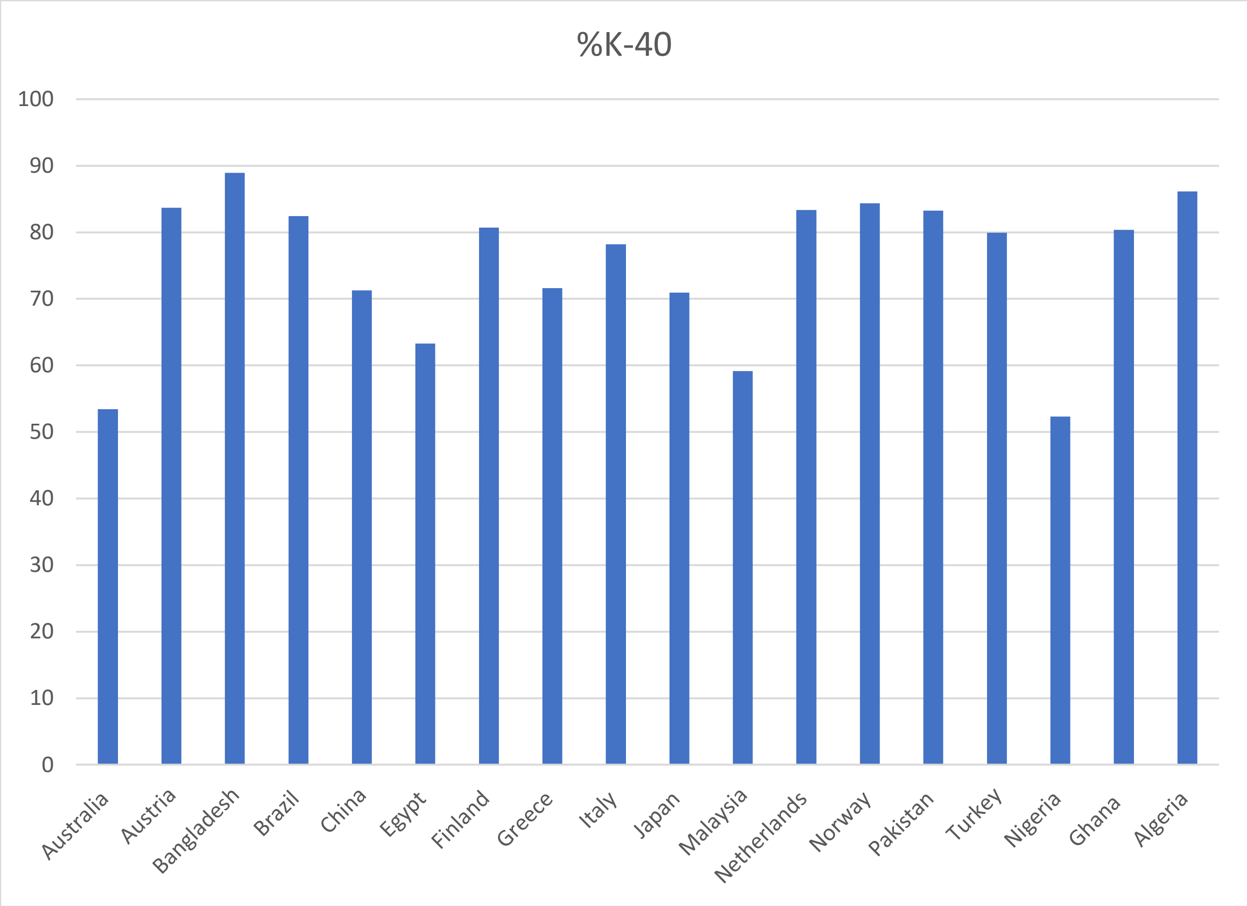

Figure 3: Country-based exposure to K-40

Figure 3 shows the proportion of exposure to potassium-40 from naturally occurring radioactive materials in the analyzed samples. The findings reveal that Nigeria has the lowest activity level of K-radionuclides, while Bangladesh exhibits the highest concentration of K-40. Additionally, the results confirm that K-40 is the most prevalent naturally occurring radioactive material (NORM) in the samples, accounting for between 52% and 88% of the total NORMs in the countries studied.

2. CONCLUSION

K-40 exposure is an unavoidable part of human existence due to its presence in nature. While the health risks associated with K-40 are generally low, it is crucial to establish robust monitoring and regulatory measures in Nigeria to ensure long-term public health safety. Addressing research gaps and increasing public awareness will help mitigate any potential risks associated with natural radiation exposure.

3. RECOMMENDATIONS

According to the results, Nigeria exhibits the lowest measured activity of potassium-40 (K-40). This indicates that Nigeria may have the least cumulative exposure to naturally occurring radioactive materials (NORMs), as K-40 is the primary contributor to activity from these materials.

To effectively manage risks and ensure public safety, Nigeria should implement the following measures:

1. Comprehensive Environmental Monitoring: Establish a national database to track K-40 levels in soil, food, and water.
2. Public Awareness and Education: Educate citizens about natural radioactivity and promote safe dietary habits.
3. Regulatory Enhancement: Strengthen existing radiation protection policies to include assessments of exposure to natural radionuclides.
4. Research and Development: Promote academic and governmental research on the health implications of K-40 exposure in Nigeria.

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