Magna Scientia Advanced Research and Reviews

eISSN: 2582-9394

Cross Ref DOI: 10.30574/msarr

Journal homepage: https://magnascientiapub.com/journals/msarr/

(RESEARCH ARTICLE)

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Radiological safety of hair creams sold in Nnewi metropolis based on natural radionuclide content

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Magna Scientia Advanced Research and Reviews, 2026, 17(01), 082-088

Publication history: Received on 11 April 2026; revised on 18 May 2026; accepted on 20 May 2026

Article DOI: https://doi.org/10.30574/msarr.2026.17.1.0076

Abstract

Background: The increasing use of cosmetic hair creams has raised concerns regarding the possible presence of Naturally Occurring Radioactive Materials (NORMs) originating from mineral-based and petroleum-derived ingredients used during production. Continuous exposure to radionuclides in cosmetic products may constitute a potential radiological health risk to consumers, thereby necessitating routine assessment of such products.

Objective: This study assessed the activity concentrations of selected radionuclides in commonly used hair creams sold in Nnewi Metropolis, Nigeria, and evaluated their potential radiological hazards to consumers.

Methods: A prospective spectrometric analytical study design was employed. Ten commonly used hair cream products were selected using convenience sampling and analyzed using calibrated gamma spectrometry techniques. The activity concentrations of potassium-40 (40K), radium-226 (226Ra), and thorium-232 (232Th) were determined and expressed in becquerels per kilogram (Bq/kg). Data obtained were analyzed using descriptive statistical methods.

Results: The results showed that 40K had the highest activity concentration among the radionuclides analyzed, ranging from 79.488 ± 4.805 Bq/kg to 138.321 ± 10.992 Bq/kg, with a mean value of 112.0995 ± 8.3864 Bq/kg. The activity concentration of 226Ra ranged from 2.316 ± 0.0806 Bq/kg to 8.836 ± 1.8432 Bq/kg, with an average value of 5.43060 ± 0.77416 Bq/kg, while 232Th ranged from 0.899 ± 0.2189 Bq/kg to 1.878 ± 1.1059 Bq/kg, with a mean concentration of 1.4206 ± 0.60596 Bq/kg. Variations in radionuclide concentrations among the hair cream products were attributed to differences in raw material composition, geographical origin of ingredients, and manufacturing processes. The measured activity concentrations were below internationally recommended radiological safety limits for consumer products, indicating minimal radiological risk associated with the routine use of the investigated hair creams.

Conclusion: The investigated hair cream products sold in Nnewi Metropolis have measured radionuclide concentrations below internationally recommended safety limits. However, periodic radiological monitoring and regulatory surveillance of cosmetic products are recommended to ensure continued public safety and compliance with radiation protection standards.

Keywords: Hair Cream; Radioactivity; Gamma Spectrometry; Norms; Radiological Hazard

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1. Introduction

Hair is an important biological structure that contributes to protection, thermoregulation, sensory perception, and aesthetic appearance in humans (1,2). In many cultures worldwide, healthy and well-maintained hair is closely linked to beauty, confidence, social identity, and psychological well-being (3,4). As a result, there has been a significant global increase in the use of hair care products, particularly hair creams, which are commonly applied to moisturize, soften, condition, and protect the hair and scalp as part of daily personal care routines (2,3).

Modern hair creams are produced using mixtures of synthetic and naturally derived ingredients, including paraffin oil, aloe vera, coconut oil, rosemary oil, lanolin, and petroleum by-products, all of which improve cosmetic quality, texture, and shelf life (5,6). However, some of these ingredients may contain Naturally Occurring Radioactive Materials (NORMs), particularly radionuclides such as uranium-238 (^{238}U), thorium-232 (^{232}Th), radium-226 (^{226}Ra), and potassium-40 (^{40}K), which are naturally present in environmental materials (7,8). These radionuclides occur naturally in soil, rocks, crude oil, groundwater, and mineral deposits and may become concentrated during industrial extraction, refining, and manufacturing activities (9,6).

Human exposure to radionuclides can occur through various routes, including ingestion, inhalation, injection, or dermal absorption, depending on the nature of contact and environmental conditions (10,11). While hair creams are intended for external use, their frequent application to the scalp may result in low-level cumulative radiation exposure via absorption through skin pores, sebaceous glands, and hair follicles 912,13). Ionizing radiation emitted by these radionuclides—including alpha, beta, and gamma radiation—can cause biological effects such as cellular damage, oxidative stress, genetic mutations, tissue irritation, and an increased risk of cancer, depending on the absorbed dose and duration of exposure (11,14).

Historically, radioactive substances such as radium were deliberately added to cosmetic products between the 1920s and 1950s due to the belief that they possessed rejuvenating, therapeutic, and anti-aging properties (15,14). However, subsequent scientific research revealed the harmful health effects of prolonged exposure to ionizing radiation, including radiation burns, anemia, bone damage, and malignancies (14,10). Today, major radiation protection organizations—including the International Commission on Radiological Protection (ICRP), United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), and National Council on Radiation Protection and Measurements (NCRP)—acknowledge that even low-dose radiation exposure may pose a stochastic health risk, as described by the Linear No-Threshold (LNT) model (16,14).

The International Commission on Radiological Protection recommends a maximum annual public exposure limit of 1 mSv/year, excluding natural background and medical radiation exposure (16,10). Despite the increasing use of cosmetic products in Nigeria and other developing countries, limited data exist regarding the radiological safety of hair creams commonly used by the public (13,8). Therefore, this study aimed to determine the activity concentrations of selected radionuclides (^{40}K, ^{226}Ra, and ^{232}Th) in commonly used hair creams in Nnewi Metropolis and evaluate their potential radiological hazards to consumers.

2. Materials and methods

2.1. Study Area

The study was conducted in Nnewi Metropolis, Anambra State, Nigeria. Nnewi is a commercial and industrial city in southeastern Nigeria with extensive trade in cosmetic and personal care products.

2.2. Study Design

A prospective spectrometric analytical study design was employed to determine radionuclide activity concentrations in selected cosmetic hair cream products.

2.2.1. Sample Selection and Sampling Technique

Ten commonly used hair cream products available within Nnewi Metropolis were selected using a convenience sampling technique. The products included:

- Nourish Virgin
- Soul Mate

- Spotting Black Magic
- Hair Food
- So Fine
- Hair Milk
- J Star Darkening
- Purple Spotting Waves
- J Star Hair Cream
- Kakason Hair Cream

2.2.2. Sample Preparation and Instrumentation

Samples were collected in cylindrical plastic containers and hermetically sealed to prevent contamination and external interference. The samples were transported to the laboratory for gamma spectrometric analysis using pre-calibrated spectrometers.

The activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th were determined in counts per second (CPS) and converted to becquerels per kilogram (Bq/kg) using established calibration factors.

2.3. Data Analysis

Data obtained from the spectrometric analysis were analyzed using the Statistical Package for Social Sciences (SPSS) version 20.0. Descriptive statistics, including mean, minimum, maximum, and standard error of mean, were computed and presented in tables.

3. Results

Table 1 Activity Concentration of Potassium-40 (^{40}K) in Hair Cream Samples

Product	^40K (Bq/kg)	Error ±
Nourish Virgin	79.488	4.805
Soul Mate	138.321	10.992
Spotting Black Magic	102.528	9.257
Hair Food	124.416	8.637
So Fine	112.896	6.630
Hair Milk	89.856	4.805
J Star Darkening	114.048	10.992
Purple Spotting Waves	117.504	7.704
J Star Hair Cream	116.352	9.054
Kakason Hair Cream	125.586	7.339

Mean Activity Concentration: 112.0995 ± 8.3864 Bq/kg

Table 1 shows the activity concentration of potassium-40 (^40K) in the analyzed hair cream samples, with detectable levels observed in all products. The concentrations ranged from 79.488 ± 4.805 Bq/kg in Nourish Virgin Hair Cream to 138.321 ± 10.992 Bq/kg in Soul Mate Hair Cream, with a mean value of 112.0995 ± 8.3864 Bq/kg. The variation in concentrations may be attributed to differences in raw materials and manufacturing processes used in the products.

Table 2 Activity Concentration of Radium-226 (^226Ra) in Hair Cream Samples

Product	^226Ra (Bq/kg)	Error ±
Nourish Virgin	2.316	0.9677
Soul Mate	4.101	0.0806
Spotting Black Magic	7.177	0.3226
Hair Food	2.799	0.6682
So Fine	7.085	1.8432
Hair Milk	3.560	0.8986
J Star Darkening	3.571	0.1037
Purple Spotting Waves	6.947	1.7395
J Star Hair Cream	8.836	0.3802
Kakason Hair Cream	7.914	0.7373

Mean Activity Concentration: 5.43060 ± 0.77416 Bq/kg

Table 2 presents the activity concentration of radium-226 (^226Ra) in the analyzed hair cream samples. The concentrations ranged from 2.316 ± 0.9677 Bq/kg in Nourish Virgin Hair Cream to 8.836 ± 0.3802 Bq/kg in J Star Hair Cream, with a mean value of 5.43060 ± 0.77416 Bq/kg. The observed variations may be related to differences in ingredient composition and manufacturing processes.

Table 3 Activity Concentration of Thorium-232 (^232Th) in Hair Cream Samples

Product	^232Th (Bq/kg)	Error ±
Nourish Virgin	1.175	0.8064
Soul Mate	0.899	0.2189
Spotting Black Magic	1.164	0.6451
Hair Food	1.682	0.5069
So Fine	1.440	0.4378
Hair Milk	1.290	1.1059
J Star Darkening	1.740	0.3341
Purple Spotting Waves	1.682	0.5645
J Star Hair Cream	1.878	0.5414
Kakason Hair Cream	1.256	0.8986

Mean Activity Concentration: 1.4206 ± 0.60596 Bq/kg

Table 3 shows the activity concentration of thorium-232 (^232Th) in the analyzed hair cream samples. The concentrations ranged from 0.899 ± 0.2189 Bq/kg in Soul Mate Hair Cream to 1.878 ± 0.5414 Bq/kg in J Star Hair Cream, with a mean value of 1.4206 ± 0.60596 Bq/kg. The relatively low concentrations observed indicate minimal variation among the sampled products.

4. Discussion

The present study evaluated the activity concentrations of naturally occurring radionuclides in selected hair cream products commonly used in Nnewi Metropolis, Nigeria. The radionuclides investigated included potassium-40 (^{40}K), radium-226 (^{226}Ra), and thorium-232 (^{232}Th), all of which are important contributors to natural background radiation and are commonly assessed in environmental and consumer-product radiological studies (8,17). The study was motivated by increasing public use of cosmetic hair products and growing concerns regarding the possible accumulation

of Naturally Occurring Radioactive Materials (NORMs) in consumer products formulated from mineral- and petroleum-derived ingredients (9,6).

Among the radionuclides analyzed, ^{40}K recorded the highest activity concentration in all sampled products, with values ranging from 79.488 ± 4.805 Bq/kg to 138.321 ± 10.992 Bq/kg and a mean concentration of 112.0995 ± 8.3864 Bq/kg. Potassium is an essential biological element naturally present in living tissues, plants, oils, and mineral substances commonly used in cosmetic formulations (18). Its radioactive isotope, ^{40}K, is therefore expected to occur in products containing natural organic ingredients such as coconut oil, aloe vera, rosemary oil, and other botanical extracts commonly utilized in cosmetic manufacturing (6). The relatively elevated ^{40}K concentrations observed in this study are consistent with previous studies on cosmetics and personal care products, which reported that potassium-derived radionuclides usually constitute the largest proportion of natural radioactivity in cosmetic and naturally derived materials (8,17). Although ^{40}K emits beta and gamma radiation, the measured concentrations in the present study remain within levels generally considered safe for consumer products and environmental materials (17).

The activity concentration of ^{226}Ra ranged from 2.316 ± 0.0806 Bq/kg to 8.836 ± 1.8432 Bq/kg, with a mean value of 5.43060 ± 0.77416 Bq/kg. Radium-226 is a daughter product of the uranium-238 decay series and is recognized for its radiotoxicity because of its alpha-emitting properties and its ability to generate radon gas through radioactive decay (8). The presence of ^{226}Ra in the analyzed products may be associated with naturally contaminated raw materials, petroleum derivatives, or mineral-based additives used during manufacturing processes (6). Despite variations among products, the observed concentrations were comparatively lower than values reported in some studies involving cosmetic and mineral-containing consumer products from different regions (8,6). The relatively low ^{226}Ra levels observed suggest minimal radiological risk under normal conditions of use. However, prolonged and repeated exposure may contribute marginally to cumulative radiation dose, especially considering the frequent application of hair creams directly on the scalp and skin surface (6).

Similarly, the activity concentration of ^{232}Th ranged from 0.899 ± 0.2189 Bq/kg to 1.878 ± 1.1059 Bq/kg, with an average concentration of 1.4206 ± 0.60596 Bq/kg. Thorium-232 naturally occurs in rocks, soils, and mineral deposits and may be introduced into cosmetic products through naturally sourced ingredients and clay-based materials (18,6). The measured concentrations in this study were relatively low and comparable to values reported in previous investigations on cosmetic and environmental materials (8). Although thorium radionuclides possess long half-lives and contribute to external gamma exposure, the levels observed in the present study are below internationally accepted radiological safety limits for consumer products (17).

The radioactive decay relationship, $^{226}Ra \rightarrow {}^{222}Rn + \alpha$, illustrates the transformation of radium-226 into radon-222 through alpha decay, a process associated with internal radiological hazards when radionuclides accumulate in environmental or consumer materials (8). The variations observed in radionuclide concentrations among the different hair cream products may be attributed to differences in raw material composition, geographical origin of ingredients, industrial refining processes, and manufacturing practices. Products containing petroleum by-products, mineral oils, or naturally derived botanical substances may exhibit relatively higher radionuclide concentrations because these materials can accumulate NORMs from the environment during extraction and processing (6,9).

The findings of this study are important from both environmental health and radiation protection perspectives. International radiation protection agencies such as the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) emphasize that all radiation exposures should be kept As Low As Reasonably Achievable (ALARA), even when doses are relatively low (16). The importance of routine radiological assessment of consumer materials has also been highlighted in recent environmental radiation studies (17,8). Although the measured activity concentrations in the investigated hair creams were below internationally recognized radiological safety limits for consumer products, the study provides baseline data that may be useful for future monitoring and regulatory quality control of cosmetic products sold within Nigeria (9, 13).

Overall, the present findings indicate that the measured radionuclide concentrations in the assessed hair creams are below internationally recommended safety limits. Nevertheless, periodic radiological assessment of cosmetic products remains necessary to ensure public safety, establish baseline data, and promote compliance with international radiation protection standards and consumer safety regulations (6, 17).

5. Conclusion

This study assessed the activity concentrations of naturally occurring radionuclides (^{40}K, ^{226}Ra, and ^{232}Th) in selected hair cream products commonly used in Nnewi Metropolis, Nigeria, with the aim of evaluating their potential radiological

implications for consumers. The findings revealed the presence of all investigated radionuclides in the analyzed samples, confirming that cosmetic hair products may contain trace amounts of Naturally Occurring Radioactive Materials (NORMs) due to the use of mineral-based, petroleum-derived, and naturally sourced ingredients during manufacturing.

Among the radionuclides analyzed, ^{40}K exhibited the highest activity concentration across all samples, while ^{226}Ra and ^{232}Th occurred at comparatively lower levels. The predominance of ^{40}K is attributable to the natural occurrence of potassium in botanical oils and organic materials commonly incorporated into hair cream formulations. Although measurable levels of radionuclides were detected, the obtained activity concentrations remained within internationally accepted safety ranges for consumer products and did not indicate significant radiological health hazards under normal conditions of use.

The relatively low concentrations of ^{226}Ra and ^{232}Th suggest minimal contribution to external and internal radiation exposure among users. Nevertheless, because hair creams are frequently and repeatedly applied directly to the scalp, there remains the possibility of long-term cumulative exposure, especially through prolonged dermal contact. This highlights the importance of continuous radiological monitoring of cosmetic products in order to maintain exposures As Low As Reasonably Achievable (ALARA) and ensure consumer safety.

The study further demonstrated that variations in radionuclide concentrations among products may be influenced by differences in raw material composition, geological origin of ingredients, refining processes, and manufacturing practices. These findings provide important baseline radiological data for cosmetic products in Nigeria and contribute to the growing body of knowledge on environmental radioactivity in personal care products.

In conclusion, the investigated hair cream products are unlikely to pose immediate radiological risks to consumers based on the measured activity concentrations of ^{40}K, ^{226}Ra, and ^{232}Th. However, periodic radiological assessment, stricter quality control measures, and regulatory surveillance of cosmetic products remain necessary to safeguard public health and ensure compliance with international radiation protection standards. Further studies involving larger sample sizes and additional radionuclides are also recommended to expand understanding of radiological exposure from cosmetic products used in Nigeria.

Compliance with ethical standards

Acknowledgments

The authors acknowledge the technical assistance provided by the staff of the spectrometry laboratory where the sample analyses were conducted.

Disclosure of conflict of interest

The authors declare no conflict of interest.

Statement of ethical approval

Ethical approval for the study was obtained from the Faculty of Health Sciences Ethics Committee, Nnamdi Azikiwe University, Nnewi Campus.

Statement of informed consent

Community consent was also secured prior to sample collection.

Funding

The study was self-funded by the authors, and no external grant or financial support was received.

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