Evaluation of ^{40}K, ^{238}U AND ^{232}Th in Selected Cosmetics Using Gamma Ray Spectroscopy

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Abstract

Activity concentrations of Potassium-40 (^{40}K), Thorium-232 (^{232}Th) and Uranium-238 (^{238}U) in most cosmetics used by consumers are not known. Some consumers of these products may have suffered unexplained radiation -related diseases due to ignorance. This study is aimed at evaluating activity concentrations of naturally-occurring radionuclide (^{40}K, ^{232}Th and ^{238}U) in some commercially-available cosmetics. Twenty six different samples of six classes of cosmetics comprising Nail polish (Np), Lipstick (Lt), Eye-shadow (Es), Perfume (Pf), Body spray (Bs) and Powder (Pd) bought from three popular markets in Lagos State Nigeria, were evaluated for the activity concentrations of these radio-nuclides of interest using a gamma spectroscopy set-up. The results showed the activity concentrations in the samples to range from 19.54±1.36 to 1462±9.00Bq/Kg, 0.50±0.04 to 9.94±0.69Bq/Kg and 0.94±0.16 to 12.61±1.99Bq/Kg respectively for ^{40}K, ^{232}Th and ^{238}U. Potassium -40 had the highest activity concentrations in all the samples; its concentration exceeding the international threshold of 400Bq/kg in some of the samples that were analysed. The mean annual effective dose computed for all the sampled cosmetics were well below the recommended radiological limit to both the eye and skin.

Keywords**:** *Radionuclides, Uranium, Thorium, Potassium, Ionizing Radiation, Effective dose.*

1. Introduction

Cosmetics are care substances used to enhance the appearance and odour of the human body. They are mixtures of chemical compounds, derived from both natural and synthetic sources,[1]. The first evidence for the use of cosmetics was in Egypt in the fourth millennium BC [2].

Since the beginning of civilization, cosmetic products have made up one of the major constituents of the daily body care being used by not only the upper class members of the society but also by the middle and lower class members. The cosmetics industry over the past few decades had recorded a big boost by the production of various types of cosmetic products which are needed for the care and beautification of the skin, hair, nails, teeth and the body. These synthetic and/or natural sources may be associated with the presence of naturally occurring radionuclides (^{40}K, ^{232}Th and ^{238}U) that are ever present in the environment i.e in the air, water and soil. These radio-nuclides have the capacity to emit radiation naturally. According to the United Nations Scientific Committee on the Effects of Atomic Radiations reports [3], natural radiation is the largest contributor to the external dose of the world population. Uranium-238, ^{226}Ra, ^{232}Th and ^{40}K pose exposure risk externally due to their gamma ray emissions and internally due to radon and its progeny that emit alpha particles [4].

The fact that ionizing radiation produces biological effect/damage is well known. Over exposure to high amount of ionizing radiation can lead to effects like skin burns, hair loss, birth effects, cancer, mental retardation (a complex of central nervous system functional abnormality) and death [5].

Over the years, radioactive substances have been incorporated in a large variety of consumer products [6], thereby exposing the public to ionizing radiation and its possible detrimental effects. It may

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probably be assumed that the radiation dose arising from the use of cosmetic products on the human body is not likely to be high, since the quantity being applied to the body is relatively small; notwithstanding low radiation exposure over extended period have proven to be carcinogenic [7].

Little or no scientific study had been done to determine the amount of and possible effects of radio-nuclides in cosmetics, be it as intended constituents or as impurities [11]. This present study aims to determine the presence and the activity concentrations of ^{40}K, ^{232}Th and ^{238}U radio-nuclides in some selected cosmetics obtained from the three major markets; Balogun, Idumota and Ojota in Lagos State, Nigeria. Of brands that were sampled in the study, more than 85% are international brands and less than 15% of the samples are Nigeria brands.

2. Materials and Methods

2.1 Sample Collection

A total of twenty six different samples of six classes of cosmetic products (Nail polish, eye-shadow, lipstick, perfume, body spray and powder) were purchased from different shops from Balogun, Idumota and Ojota markets, Lagos State in South-Western Nigeria. The samples were labeled as shown in Table 1.

2.2 Samples Preparation and Analysis

The lipstick samples were crushed in a porcelain mortar. An average of 140.0g per sample was weighed on an electrical analytical top pan balance after which each was sealed in airtight PVC containers and kept for twenty eight days for the radionuclides and their daughter nuclides to attain equilibrium. The gamma activity of the samples were thereafter determined by a non-destructive analysis using a computerized gamma ray spectrometry with a Thallium doped Sodium-Iodide (NaI) detector (well type) and photomultiplier tube at the National Institute of Radiation Protection and Research in Physics Department, University of Ibadan, Oyo state. A Thallium doped Sodium-Iodide (NaI) detector (well type) and photomultiplier tube with a universal spectrometer (UniSpec) multichannel analyzer, (Model № 22060316) with computer interface for data acquisition were used. The activity concentration of ^{238}U was calculated from the average peak energies of 1746.49kev of ^{214}Bi, and 609.31 keV of ^{214}Bi, while that of ^{232}Th was determined from the average energies of 238.63 keV of ^{217}Pb and 911.21 keV of ^{228}Ac. The activity concentration of ^{40}K was determined from the energy 1460.83 keV.

The analytical expression used in calculating the activity concentration is as given by Nguelem *et al.*,[8] as:

$$A_{ac} = \frac{N_{sam} e^{\lambda T_d}}{P_E \varepsilon(E) T_C M} \qquad (1)$$

where A_{ac} = the activity concentration,
λ = the decay constant,
N_{sam} = total net counts for the sample in the peak range,
P_E = gamma-ray emission probability,
T_d = the decay time between the sampling and counting,
T_C = the counting time,
$\varepsilon(E)$ = the total counting efficiency of the detector system,
M = the mass of sample (kg) or volume (L) and
$e^{\lambda Td}$ = the correction factor for decay between sampling and counting [9].

3. Results

Figure 1 shows the masses of the samples at the point of collection and sealing, prior to the attainment of equilibrium between the long-lived parent

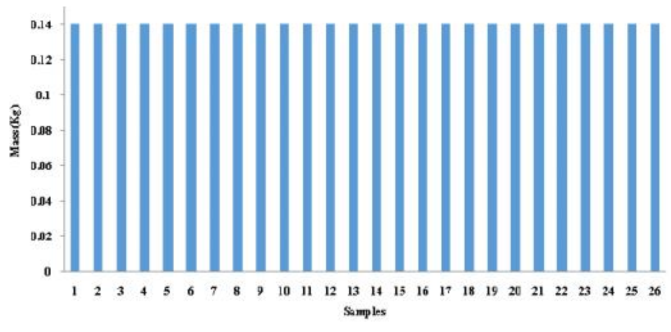

Figure 1: Day 1 Mass (Kg) of Samples

Table 1: Classes of Cosmetic Products Analyzed

S/N	*Samples Class*	*Samples Code*
1	Nail-polish (n = 5)	Np-1
2		Np-2
3		Np-3
4		Np-4
5		Np-5
6	Eye-shadow (n = 5)	Es-6
7		Es-7
8		Es-8
9		Es-9
10		Es-10
11	Lipstick (n = 5)	Lt-11
12		Lt-12
13		Lt-13
14		Lt-14
15		Lt-15
16	Perfume (n = 5)	Pf-16
17		Pf-17
18		Pf-18
19		Pf-19
20		Pf-20
21	Body spray (n = 5)	Bs-21
22		Bs-22
23		Bs-23
24		Bs-24
25		Bs-25
26	Powder (n = 5)	Pd-26

radio-nuclides and their short-lived daughter radio-nuclides. The average masses for each of the sample were 140.0g. Figure 2 is the measurement of the mass of the samples after equilibrium in 28days. There were observable changes in the masses of each sample. This observable phenomenon could not be properly explained, since the PVC containers were airtight and sealed. However, these may be adduced to some transmutational changes, since most

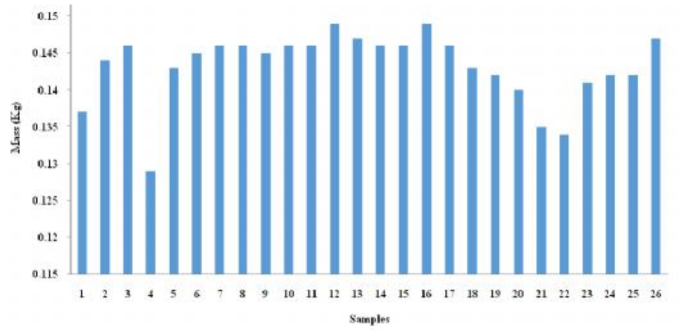

Figure 2: Mass (Kg) of Samples after 28 Days

of the samples appreciated and few others depreciated. The depreciated ones Np-1, Np-4, Bs-21 and Bs-22 may be due to the volatility of the cosmetics sam-

Table 2: Specific Activity Concentrations of ^{40}K, ^{232}Th and ^{238}U (Bq/Kg or Bq/L) of Cosmetic Samples

Liquid Samples			
Sample Code	***^{40}K (Bq/L)***	***^{238}U (Bq/L)***	***^{232}Th (Bq/L)***
Np-1	176.04±12.00	1.27±0.24	BDL
Np-2	386.01±27.00	3.81±0.67	BDL
Np-3	134.54±9.10	BDL	BDL
Np-4	BDL	1.34±0.24	1.09±0.08
Np-5	BDL	1.43±0.29	BDL
Pf-16	191.92±13.00	BDL	**9.94±0.69**
Pf-17	44.05±3.09	BDL	BDL
Pf-18	157.45±10.00	BDL	BDL
Pf-19	135.08±9.20	5.53±1.00	BDL
Pf-20	158.87±11.00	BDL	BDL
Bs-21	341.96±23.00	BDL	BDL
Bs-22	369.32±25.00	BDL	8.75±0.63
Bs-23	132.03±9.10	0.94±0.16	BDL
Bs-24	*19.54±1.36*	*1.59±0.29*	*4.62±0.33*
Bs-25	97.70±7.06	BDL	4.88±0.35
Solid Samples			
Sample Code	***^{40}K (Bq/Kg)***	***^{238}U (Bq/Kg)***	***^{232}Th (Bq/Kg)***
Es-6	*1462.36±9.00*	BDL	BDL
Es-7	1422.21±9.00	BDL	7.56±0.55
Es-8	970.72±63.00	BDL	BDL
Es-9	*973.09±63.00*	*12.61±1.99*	*7.44±0.55*
Es-10	798.82±53.00	11.83±2.16	BDL
Lt-11	218.26±15.00	6.41±1.09	BDL
Lt-12	631.55±42.00	8.65±1.61	BDL
Lt-13	*143.04±10.00*	*5.72±1.03*	*0.50±0.04*
Lt-14	338.81±23.00	BDL	BDL
Lt-15	375.84±25.00	BDL	5.55±0.40
Pd-26	657.34±45.00	9.78±1.64	BDL

BDL= Below Detection Limit.
Detection Limits; ^{40}K= 4.030Bq/Kg, ^{232}Th= 0.107Bq/Kg and ^{238}U= 0.258B/Kg.

ples even though they are airtight. The specific activity concentrations of the radio-nuclides of interest are shown in Table 2

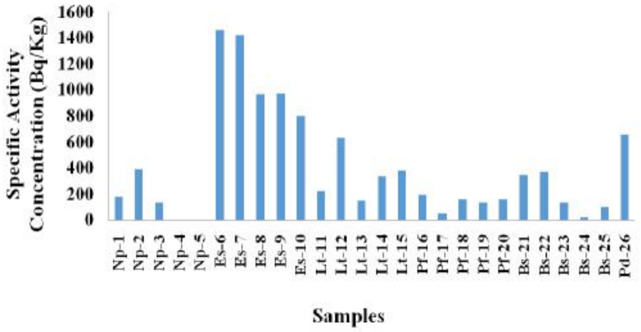

Fig. 4: Specific activity concentration of ^{40}K in samples

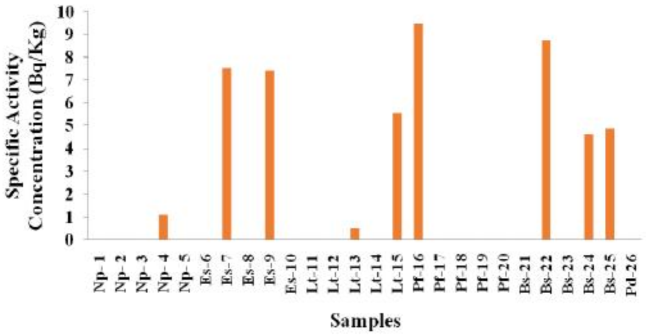

Fig. 5: Specific activity concentration of ^{232}Th in samples

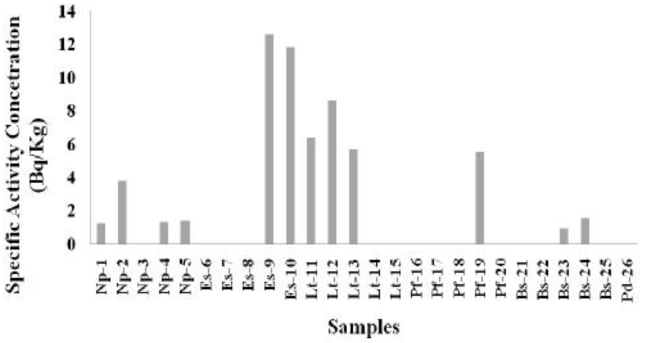

Fig. 6: Specific activity concentration of ^{238}U in samples

4. Discussion

The activity concentrations of the radio-nuclides being examined are observed to be higher in all the solid samples than the liquid samples (as seen from Table 2). It thus follows that greater radiation risk is

Table 3: The effective doses resulting from radionuclide presence in sampled cosmetics

	^{40}K (nGy/h)	^{238}U (nGy/h)	^{232}Th (nGy/h)	Total effective dose (nGy/h)	Annual effective dose (mSv)
Nail Polish					
Np-1	0.076	0.005	-	0.081	0.255
Np-2	0.166	0.016	-	0.182	0.574
Np-3	0.058	0.000	-	0.058	0.183
Np-4	-	0.006	0.007	0.013	0.041
Np-5	-	0.006	-	0.006	0.019
Average	**0.06**	**0.007**	**0.001**	**0.068**	0.214
Perfume					
Pf-16	0.083	-	0.066	0.148	0.467
Pf-17	0.019	-	-	0.019	0.060
Pf-18	0.068	-	-	0.068	0.214
Pf-19	0.058	0.024	-	0.082	0.259
Pf-20	0.068	-	-	0.068	0.214
Average	0.0592	0.005	0.013	0.077	0.243
Body Spray					
Bs-21	0.147	-	-	0.147	0.464
Bs-22	0.159	-	0.058	0.217	0.684
Bs-23	0.057	0.004	0.000	0.061	0.192
Bs-24	0.008	0.007	0.031	0.046	0.145
Bs-25	0.042	-	0.032	0.074	0.233
Average	0.0826	0.002	0.024	0.109	0.344
Eye Shadow					
Es-6	0.629	-	-	0.629	1.984
Es-7	0.612	-	0.050	0.662	2.088
Es-8	0.417	-	0.000	0.417	1.315
Es-9	0.418	0.054	0.049	0.522	1.646
Es-10	0.343	0.051	-	0.394	1.243
Average	0.4838	0.021	0.020	0.5248	1.655
Lipstick					
Lt-11	0.094	0.027	-	0.121	0.382
Lt-12	0.272	0.037	-	0.309	0.974
Lt-13	0.062	0.024	0.003	0.089	0.281
Lt-14	0.146	-	-	0.146	0.460
Lt-15	0.162	-	0.037	0.198	0.624
Average	0.1472	0.0176	0.008	0.1726	0.544
Powder					
Pd-26	0.283	0.042	0.000	0.324	1.022

likely to be associated with the use of the solid cosmetics than the liquid ones, all other factors being kept constant. Potassium-40 concentrations in all samples were higher than those of ^{238}U and ^{232}Th. Its natural abundance in the earth [10] and consequently in some of the constituents from which the cosmetics were made may account for this [11]. Potassium-40 has the highest concentration in E_S cosmetic samples. Its activity concentration in samples Es-6, Es-7, Es-8, Es-9, Lt-12 and Pd-26 are higher than the international accepted value of 400Bq/Kg [3]. It is however below detection limit in Np-4 and Np-5. Thorium-232 is also below detection limit in most of the samples, which means its presence is insignificant in the constituents of the sampled cosmetics, (Figures 4 to 6).

The mean values of the activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the sampled cosmetics are 430.68±21.54, 5.60±0.22 and 5.45±0.68 Bq/kg respectively. Both ^{238}U and ^{232}Th concentrations in all samples fell below the recommended values of 30 and 35 Bq/Kg respectively [3]. The average hourly effective dose (E) that is associated with radiation exposure from the use of these cosmetics is determined to evaluate the health risk to the public. Calculations are based on inhalation of the radio-nuclides present in the cosmetics. The effective dose is given by:

$$E = \sum_T W_T \sum_R W_R D_{T,R} \qquad (2)$$

where W_R = the radiation weighting factor,
W_T = the tissue weighting factor and
D = the absorbed dose rate.

The absorbed dose rate D is obtained using the formulae: [12],[13]

$$D = 0.427A_{U-238} + 0.662A_{Th-232} + 0.043A_{K-40} \qquad (3)$$

where A = the activity concentration measured in Bq/ kg
and the constants 0.427, 0.662 and 0.043 nGy/h per Bq/kg are the dose conversion factors for ^{238}U, ^{232}Th & ^{40}K respectively [3]

Radiation weighting factor, W_R for the gamma radionuclides being investigated and tissue weighting factor W_T for the skin are 1 and 0.01 respectively [14].

The average annual effective dose (AED) is obtained by adding up the hourly effective doses for a whole year. In this work, it is assumed that the cosmetics stay on the body for 12 hours. This amounts to an ‘occupancy factor’ of 0.5. The annual effective dose is thus given as:

$$AED\ (Sv) = E * OF * T * 0.72 \qquad (4)$$

where E = the average hourly effective dose,
OF = the occupancy factor,
T = the time (8760 hours) and
factor 0.72 = conversion coefficient ($SvGy^{-1}$) for an absorbed dose in air to effective dose in human body, [4].

The computed effective doses for the radio-nuclides in the samples are shown in Table 3.

The total annual effective doses are less than 1.0 mSv for all the sampled cosmetics except the eye shadow (E_S) and powder (Pd) which have average annual effective dose values of 1.66 and 1.02 mSv respectively. It follows that use of these two cosmetics will put the public at a higher radiation risk compared to other sampled cosmetics. The mean annual effective dose for E_S in this work compare favourably to the total effective dose (gross alpha and gross beta) reported for E_S in commercially - available cosmetics in Turkey [11]. The least risk is associated with the use of nail polish, which has an effective dose of 0.214 mSv/y.

Radiation exposure to the eye lens and skin is expected not to exceed 15 and 50 mSv/y respectively [15] [16]. All the sampled cosmetics in this present work have dose values that are well below these recommended limits, thus making them to pose no radiological health risk to the users.

5. Conclusion and Recommendation

Radionuclide analyses of twenty six different samples of six types of cosmetic products (nail polish, eye-shadow, lipstick, perfume, body spray and powder) were carried out using a NaI detector gamma ray spectrometry system. The samples were analyzed for the specific activity concentrations of the three types of radio-nuclides ^{40}K, ^{232}Th and ^{238}U. The results obtained indicated that the radio-nuclides were present in the selected cosmetics samples and at varying activity concentration. Potassium-40 in all the samples of eye-shadows, lipsticks sample Lt-12 and powder sample Pd-26 have activity concentration that are above the permissible level of 400Bq/Kg for ^{40}K UNSCEAR [3].

The degree of presence of the radio-nuclides of interest in the six classes of selected cosmetic products is as follows: eye-shadow- $^{40}K>^{238}U>^{232}Th$; powder- $^{40}K>^{238}U>^{232}Th$; lipstick- $^{40}K>^{238}U>^{232}Th$; nail polish- $^{40}K>^{238}U>^{232}Th$, body spray- $^{40}K>^{232}Th>^{238}U$ and perfume- $^{40}K>^{232}Th>^{238}U$ respectively. The results revealed that cosmetics serve as additional external and internal source of radiation exposure, although its contribution is minimal and radiologically unharmful.

The results obtained in this work can be used as baseline information for further radiation analysis on cosmetic products.

There exists a possibility of ingestion of cosmetics (e.g. lipsticks) or its absorption into the body (e.g. body spray) through wounds. Consequently, a complete analysis of alpha and beta particle and gamma content in cosmetic samples and their associated dose is strongly recommended. This will provide a comprehensive result that can assist relevant bodies to come up with proper safety guidelines and legislations for the manufacture and use of cosmetics.

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