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ACTIVITY CONCENTRATION AND RADIOLOGICAL HAZARD INDICES FROM CONSUMER PRODUCTS IN NIGERIA

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ABSTRACT

This study focuses on the evaluation of the natural radioactivity levels in twenty-five samples of consumable products (Fruit juice, soap/detergent, toothpaste, body cream and face powder) that are available in Port Harcourt markets. The specific activities of radium, thorium and potassium using gamma spectroscopy and radiation hazard indices using radiation models were determined. The results of the mean activities of radionuclides (^{40}K, ^{226}Ra and ^{232}Th) for fruit juices, soap/ detergent powders samples, toothpastes samples, body creams and face powder samples were found to be (328.73 ± 19.08) Bq/l , (423.79 ± 22.73) Bq/kg, (349.45±18.05) Bq/kg, (236.95±17.87) Bq/kg and (325.63±14.20)Bq/kg respectively for ^{40}K while the mean specific activities of ^{226}Ra were (14.21 ± 6.28) Bq/l , (15.70 ± 17.56) Bq/kg , (11.47±4.50)Bq/kg, (15.95± 6.77) Bq/kg and (18.65±6.94)Bq/kg respectively and the mean specific activity of ^{232}There were (282.29 ± 6.07) Bq/l, (286.13 ± 4.164) Bq/kg, (336.37±16.09) Bq/kg, (192.91±13.96) and (341.56±18.24) Bq/kg respectively. The annual effective dose and excess lifetime cancer risk estimated for infants, children, teenagers and adults that drinks fruit juices sampled showed that infant and teenagers will be impacted having the mean values of 3.43 $mSvy^{-1}$ and 2.444 $mSvy^{-1}$ respectively. The excess lifetime cancer risk values exceeded their safe limits for all the age brackets while radium equivalent activity, the external hazard index and the internal hazard index due to natural radioactivity in soap/detergents, toothpastes, body cream and face powder samples estimated above the regulatory standard recommended which are 370 Bq/kg and 1 respectively. The results showed that the consumable products studied except the fruit juice do not have harmful radiological impact on the consumer.

Key words: *Radioactivity, detergents, Fruit juice, spectroscopy, Port Harcourt market*

INTRODUCTION

The foods that we eat and fruits we drink may contribute to some extent to our internal exposure to radiation. These foods and fruits are naturally radioactive. Fruit juice consumption has become a worldwide dietary habit and, as a result, the consumption of frozen concentrated juice has increased steadily over the years (Adeniji et al., 2013). Not surprisingly, the market share of this product is now much greater than that of fresh fruit, especially in the major cities in the countries. Naturally occurring radionuclides enter the human body mainly by inhalation of radon and thoron gases and their decay products (Misdaq et al., 2001) and by ingestion of primordial radionuclides and their progeny, ^{40}K, and the ^{238}U and ^{232}Th series (Fisenne et al., 1987; Shiraishi et al., 2000; Kumahara et al., 1997). The ingested radionuclides could be concentrated in certain parts of the body for example ^{238}U accumulates in human kidney and lungs, ^{232}Th in liver, skeleton tissue and lungs and ^{40}K in muscles (Tawalbeh et al., 2012). The accumulation of these radionuclides in any organ in the body will affect the health condition which may result to inducing various forms of diseases, weakening the immune system and also contributing to increased mortality rate. Natural sources of radiation– a combination of cosmic and terrestrial radiation - represent the major part of radioactivity in the food chain. Radionuclides such as ^{40}K, ^{226}Ra that occur naturally in soil are incorporated metabolically into plants and ultimately find their way into foods and water (Eisenbud and Gesell, 1997).

Detergents play an important role in the daily life and are considered as helping factor to maintain health, house and clothes cleaning and keeping a healthy environment by getting controlling dirt, germs and so on (Spitz, 2004). Today's detergents are composed of several materials with different rates; these are: active matter, phosphates/zeolites, soddash, sodium silicate sodium sulphate, sodium chloride, clay and moisture (Ho Tan Taı̂ and Nardello-Rataj, 2008; Myers, 2006). Detergents are as all the other industrial products consist of the elementary materials (ethanol, diethyl ester dimethyl ammonium chloride, cyclodextrin, citric acid, carboxymethyl cellulose, amine oxide, alkyl ethoxy sulfate and alkyl sulfate anionic surfactant). So, it is important to be familiar with their natural radioactivity level through the radiant elements in their raw materials derived from the nature, animals, plants, metals, fossil fuel or oil (Michael and Showell, 2005). In addition, detergents are the first group that contains chemical materials like phosphate containing radiant elements which may be transferred to consumer of products and it increased health impacts on the people.

Soaps are made from many different sources such as oils, animal fats, and plants, while detergents were from oils (hydrocarbon compounds of petroleum or coal). Long-lived radioactive elements include uranium, thorium and potassium and any of their decay products, such as radium and radon (Merrill and Gressel, 1997; Garner et al., 2001; Henner and Garcia-Sandez, 2002) exists in the environment. Radium and uranium may be taken up by different cleaning materials such as soap and powder detergent, which are usually used by people daily.

Public radiation exposure from uranium mainly occurs through the surface and ground water pathway and contamination of foodstuffs and materials which are used by human as toothpaste, cleaning materials, building materials or any materials in environmental (Sing and Vir, 1984). Toothpastes consist of various components: water (20–40%), abrasives (50%) including aluminum hydroxide, calcium hydrogen phosphates, calcium carbonate, silica and hydroxyapatite. Fluoride (usually 1450 ppm) mainly in the form of sodium fluoride (Kurosaka et al., 2013). There are minerals (inorganic and organic) matters present in the toothpastes, generally contaminated

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with minor amounts of uranium (Baykura *et al*., 2007). There have been studies on uranium concentration in materials which are used for human consumables in several countries. Surrender Singh *et al*. (1984) reported a uranium concentration in toothpastes and fruit juices of 0.91-3.56 ppm for different toothpastes used in the Indian market. Mahdi *et al.,* (2014) also reported uranium concentration of 1.07 - 3.57 ppm in toothpaste collected from national market in Iraq.

The skin, the body's largest organ, is found at the interface between the external and internal environments, and thus is strategically placed to provide a barrier against noxious stressors (UV radiation, mechanical, chemical and biological insults) (Tobin, 2006). Cosmetic products can be applied to the face as skincare cream, lipstick, eye shadow etc; to the body as cellulite cream, perfume and baby product; to the hands/nails as hand cream and nail polish; and to the hair as shampoo, hair spray, and gel. A large population including children, young and elderly people commonly use cosmetic products. Therefore, some research work revealed various concentrations of radionuclides in these consumer products (Sherif et al., 2015; Briggs-Kamara, 2012; Furuta et al., 2008; Papadopoulos et al., 2014; Medhat et al., 2015). However, there are no studies involving the radiological hazards associated with human exposure due to the usage of those products. Studies have shown that exposure to high level of radionuclides can lead to radiation related health risk such as skin cancer, necrosis, cataracts and many others (Omar et al., 2018). It is therefore, important to determine the activity concentration of radionuclides in consumer products in order to quantify their radiological health risk to the users. In this study, the activity concentration of radionuclides in fruit juice, toothpaste, face powder, soaps and detergent and creams and pomade consumed in Rivers state, Nigeria was determined and analysis of radiological health hazard associated with their usage was performed.

MATERIALS AND METHOD

Consumer product samples were purchased from different markets in Port Harcourt, and a representative variety were selected: 5 different samples of fruit juice, 5 samples of different types of toothpaste (all Nigerian product), 5 samples of face power (both foreign and local), 5 samples of soaps and detergents and 5 samples of creams and pomade (local and imported) as presented in Table 1.

Sampling and Sample Preparation

A total of twenty five samples of selected consumer products were collected and analyzed at Federal University of Agriculture Abeokuta (FUNAB), Ogun State using gamma ray spectrometer. Five marinelli beakers for five different fruit juice samples and one for recording the background counts, were washed, rinsed with diluted H_2SO_4 acid to prevent the samples from being contaminated, and then dried. These clean marinelli beakers were then filled with the bottled fruit juices of different varieties, sealed and reweighed. The weight of each sample was then recorded and samples codes were indicated on the beaker. The sealed samples were kept for minimum of twenty eight days to enable them reach a secular equilibrium before counting commenced.

Five detergent powders were prepared for analysis by drying, and keeping them moisture-free by putting in an oven. To reach a suitable homogeneity, the samples were electrically crushed, using a micro mill. In order to get homogeneity, the samples were sieved through of 0.8mmpore size diameter. All samples were stored for about four week before counting, to allow secular equilibrium to be attained between ^{222}Rn and its parent ^{226}Ra in uranium chain (Nasim et al., 2012).

The fifteen different cosmetic samples were obtained from the cosmetic markets. Of brands that were sampled in the study, 80% are international brands and only 20% of the samples are Nigerian products brands. All samples were dried at 105 °C in an oven for 24 hours so as to remove completely the moisture. The dried samples were sieved through a stainless steel sieve (75 mm) and were packed into the plastic containers which were kept sealed for 4 weeks to achieve secular equilibrium. This step is necessary in order to ensure that radon was confined within the volume and the daughters remain in the samples (Medhat et al., 2015). Finally, all samples were counted to determine the specific activity of radionuclides using gamma spectrometry.

Table 1: Consumer Products and Country of Origin

S/N	Sample ID	Product Name	Country of origin
A. Fruit Juice			
1	FJ1	Citron	Nigeria
2	FJ2	Citron with sugar +Sweetener	Nigeria
3	FJ3	Strawberry drink	Ireland
4	FJ4	Yoghurt drink	Sri Lanka
5	FJ5	Tiger nut	Nigeria
B. Toothpaste			
6	TP1	Deep action	Nigeria
7	TP2	Pro-Health	Nigeria
8	TP3	Fluoride paste	Nigeria
9	TP4	Herbal	Nigeria
10	TP5	Triple protection	Nigeria
C. Powders			
11	FP1	Cool refreshing	Nigeria
12	FP2	Quality powder	Nigeria
13	FP3	Talcum	Nigeria
14	FP4	Antiseptic Absorbent	Nigeria
15	FP5	Perfumed Talc	Malaysia
D. Soap/Detergent			
16	SD1	Complexion	London
17	SD2	Medicated Soap	Zheijiang (China)
18	SD3	Pure white antibacterial soap	Nigeria

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19	SD4	Quick action	Sri Lanka
20	SD5	Freshener petal	Nigeria
E. Body Cream			
21	BC1	Crème cream	Abidjan
22	BC2	Cream with olive oil (peas)	Nigeria
23	BC3	Luxuriant moisturizer	Nigeria
24	BC4	Body cream	Honiara
25	BC5	Cleansing Medicated cream	Nigeria

Instrument and Calibration

Radioactivity measurements were performed by gamma ray spectrometry which consists of NaI(Tl) detector and multichannel analyzer (4096 channel) of desperation energy (FWHM) in the peak 1.33 KeV for ^{60}Co at 7%. The radioactive background decreases for different radiations by using shield which consists of two layers, first one of stainless steel with width (10 mm) and the second layer lead (30 mm). Energy calibration and efficiency calibration of gamma spectrometer were carried out using (Co-60,Cs-137, Na-22) calibration sources in 1 liter Marinelli beaker covering the energy from 25 KeV to 2500 KeV. Energy calibration of the detector system is performed by measuring mixed standard sources of known radionuclides with well-defined energies within the energy range of interest, usually 60–2000 keV (IAEA, 1989). Each sample beaker was placed on the detector surface which was enclosed by a lead shield. The shield was tightly closed. The power supplied to the detector is through A/C stabilizer. The system was preset to 36000 seconds (counting time). Each sample was counted twice in order to check the stability of counting system.

Determination of Specific Activity of Radionuclides

The samples were placed on the detector and measured for a period of 18,000 s. To calculate the specific activity for each sample, the net area under the corresponding peaks in the energy spectrum was computed by subtracting count due to background sources from the net area of a certain peak using MAESTRO-32 data analysis package. The background spectrum was measured by using Empty 1 l polyethylene plastic Marinelli beakers on the detector and counting under the same time for the sample measurements. Because of the poor resolution of NaI (Tl) detector, at low gamma energies which haven't well-separated photo-peaks, thus the measuring of the activity concentrations is possible at a good separated photo-peaks at high energies as that obtained in our results from the gamma rays emitted by the progenies of ^{238}U and ^{232}Th which were in secular equilibrium with them while, ^{40}K was estimated directly by its gamma-line of 1460 keV.

Hence the specific activity of ^{226}Ra was determined using the gamma-lines 1765 keV (^{214}Bi). The corresponding results of ^{232}Th were determined using the gamma-ray lines 2614 keV (^{208}Tl).

The specific activity of each radionuclide is can be calculated using the following equation (Jose et al., 2005):

$$Ac = \frac{C - BG}{\epsilon\% I\gamma tm} \quad (1)$$

where Ac is the specific activity, C is the area under the photo peaks, ε% is the Percentage of energy efficiency. Iγ is the percentage of gamma-emission probability of the radionuclide under consideration, t is counting time, m is mass of sample and BG is background count.

RADIOLOGICAL RISK ASSESSMENT

Annual Effective Dose Equivalent and Excess Lifetime Cancer risk

The annual effective dose from ingestion of radionuclide in fruit juice samples was estimated on the basis of the mean activity concentration of the radionuclides. This was done for different age brackets. In this work, the intake rates and dose conversion factors for the radionuclides based on the International commission on radiological protection (ICRP, 2012) publication are used: 0.5 L/day and 1.0 l/day for infants (age ≤ 1yr) and Children (age 1-12 years) respectively. And 2 L/day for teenagers (≤ 17yr) and adult (> 17 yrs) as presented in Table 2.

The annual effective dose from ingestion of ground water was computed by the following equation (Ndontchueng *et al.*, 2014).

$$H_{ing}(w) = \sum DCF_{ing\,(i)} \times A_{spi} \times I \quad (2)$$

DCFing is dose conversion coefficient of a particular radionuclide ith in Sv/Bq for a particular age category, Aspi is the specific activity concentrations of radionuclide ith in the water samples in Bq/l and I is radionuclide intake in litres per year for each age category.

In addition to the estimated annual effective dose, the cancer and hereditary risk due to low dose without any threshold dose known as stochastic effect were estimated using the ICRP cancer risk model (ICRP, 2007). Radiation risk to population result from exposure to low dose radiation are normally known as chronic risk of somatic or hereditary damage of human tissues, thus much emphasis is always placed on the reduction of these radiological risks to natural radiation.

The nominal lifetime risk coefficient of fatal cancer recommended in the 2007 recommendations of the ICRP for members of the public is $5.5 \times 10^{-2}\ Sv^{-1}$. For hereditary effects, the detriment adjusted nominal risk coefficient for the whole population as stated in ICRP (ICRP, 2007) for stochastic effects after exposure at low dose rates is estimated at $0.2 \times 10^{-2}\ Sv^{-1}$.

The risk to population was then estimated using the recommended risk coefficient in ICRP report and assumed 70 years lifetime of continuous exposure of population to low level radiation. According to the ICRP methodology:

Cancer Risk = Total annual Effective Dose (Sv) x cancer risk factor (3)

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Table 2: Committed Effective Dose Conversion Factor (Sv/Bq) for members of the Public (ICRP, 2012)

S/N	Radioisotope	Infant ≤ 1yr	Children (1-12yr)	Teenage (12-17)	Adult ≥ 17yr
1	^{226}Ra	4.7 E-06	6.2 E-07	1.5 E-06	2.8 E-07
2	^{232}Th	3.0E-05	3.4 E-06	5.3 E-06	6.2 E-07
3	^{40}K	6.2 E-08	2.1 E-08	7.6 E-09	6.2 E-09
	H_2O Intake	0.5 L	1.0 L	1.5 L	2.0 L

Radium Equivalent Index

Radium equivalent (Ra_{eq}) is an index use to compare the activities of ^{40}K, ^{238}U and ^{232}Th contained in substance by a single quality and which takes into account the radiation hazards associated with them (Avwiri *et al*, 2012). The index gives useful guideline in regulating the safety standard of living. This index is a weighted sum of activities of ^{40}K, ^{238}U and ^{232}Th. The radium equivalent activity index is given in the equation below:

$$Ra_{eq} = C_{Ra} + 1.43\ C_{Th} + 0.077C_k \qquad (4)$$

where C_{Ra}, C_{Tn} and C_k are the radioactivity concentration in Bq/kg of ^{238}U, ^{232}Th, and ^{40}K

External and Internal Hazard Indices

The external hazard index (Hex) is used for the evaluation of external exposure to gamma radiation in (lie outdoor air. It can be calculated using the equation below (Senthilkumar, *et al.,* 2010).

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (5)$$

Where A_{Ra}, A_{Th}, and A_k are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K respectively. This expression indicates that the value of this index must be less than unity in order to keep the radiation hazard to be insignificant. Thus, the maximum values of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} being 370 Bq/kg.

Considering the hazardous nature of internal exposure to ^{222}Rn and its decay products to the lung and other respiratory organs and the fact that reducing the ^{226}Ra to half of its maximum acceptable limit for external exposure only will make H_{in} the internal hazard index less than unity, thus the internal hazard index H_{in} is given by the equation below (Senthilkumar *et al.*, 2010).

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \qquad (6)$$

Where A_{Ra}, A_{Th}, and A_k are the activity concentration of ^{226}Ra ^{232}Th and 4^0K respectively. The values of the indices H_{in}, and H_{ex} must be less than one for the radiation hazard to be negligible. Internal exposure to radon is very hazardous; it can lead to respiratory diseases like asthma and cancer.

RESULTS

The specific activity concentrations of ^{40}K, ^{226}Ra, and ^{228}Ra (^{232}Th) identified in consumer product samples from Port Harcourt metropolis as well as their radium equivalent (Raeq), external hazard index and internal hazard are presented in Table 3- 7 while Table 8 shows the radiological health risk estimated from activity concentration of radionuclides in fruits.

Table 3: Activity Concentration of Radionuclides in Fruit Juice Samples

S/N	Sample ID	^{40}K (Bq/l)	^{226}Ra (Bq/l)	^{232}Th (Bq/l)	Ra_{eq} (Bq/l)	H_{ex}	H_{in}
1	FJ1	193.78±25.20	8.45±4.75	382.03±6.53	569.67	1.54	1.56
2	FJ2	333.18±15.30	0.48±6.21	372.99±5.72	559.51	1.51	1.51
3	FJ3	420.31±15.90	10.23±4.05	350.38±6.31	543.64	1.47	1.50
4	FJ4	488.07±14.00	16.43±6.21	23.74±5.72	87.96	0.24	0.28
5	FJ5	208.30±25.00	35.48±10.19	BDL	51.52	0.14	0.24
	Mean	**328.73±19.08**	**14.31±6.28**	**282.29±6.07**	362.46	0.98	1.02

Table 4: Activity Concentration of Radionuclides in Toothpaste Samples

S/N	Sample ID	^{40}K (Bq/l)	^{226}Ra (Bq/l)	^{232}Th (Bq/l)	Ra_{eq} (Bq/l)	H_{ex}	H_{in}
1	TP1	454.19±24.05	2.69±1.10	374.12±9.58	572.65	1.55	1.55
2	TP2	475.49±12.20	4.91± 2.10	292.74±11.76	460.14	1.24	1.26
3	TP3	270.26±17.50	9.78±1.50	281.43±8.91	433.03	1.17	1.20
4	TP4	184.10±24.40	31.05±13.20	201.19±25.32	332.93	0.90	0.98
5	TP5	363.19±12.11	8.90±4.62	532.35±24.91	798.13	2.15	2.18
	Mean	**349.45±18.05**	**11.47±4.50**	**336.7±6.07**	**519.38**	**1.40**	**1.43**

Table 5: Activity Concentration of Radionuclides in Face Powder Samples

S/N	Sample ID	^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}
1	FP1	282.84±17.00	10.67±8.16	375.25±15.70	569.06	1.54	1.57
2	FP2	350.60±11.00	27.95± 5.70	307.43±16.89	494.57	1.34	1.41
3	FP3	312.85±14.00	24.85±6.67	365.07±28.41	570.99	1.54	1.61
4	FP4	360.29±13.00	20.86±8.16	388.81±16.60	604.60	1.63	1.69
5	FP5	321.56±16.00	8.90±6.03	271.26±13.60	421.56	1.14	1.16
	Mean	**325.63±14.20**	**18.65±6.94**	**341.56±18.24**	**532.16**	**1.44**	**1.49**

Table 6: Activity Concentration of Radionuclides in Soap/detergent Samples

S/N	Sample ID	^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}
1	SD1	585.85±11.50	11.48±6.94	162.76±10.62	439.64	1.19	1.22
2	SD2	403.85±50.23	5.80± 13.25	495.05±9.54	339.90	0.10	0.12
3	SD3	522.92±15.34	21.30±7.02	302.91±25.32	294.31	0.79	0.85
4	SD4	404.82±19.60	34.59±14.80	307.15±13.56	773.68	2.09	2.18
5	SD5	201.52±17.02	5.35±10.91	162.76±10.62	454.03	1.23	1.24
	Mean	**423.79±22.73**	**15.70±7.56**	**495.05 ±9.54**	**460.31**	**1.08**	**1.12**

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Table 7: Activity Concentration of Radionuclides in Body Cream Samples

S/N	Sample ID	^{40}K (Bq/kg)	^{226}Ra (Bq/kg)	^{232}Th (Bq/kg)	Ra_{eq} (Bq/kg)	H_{ex}	H_{in}
1	BC1	105.68±12.30	35.30±8.41	22.26±11.52	75.27	0.20	0.30
2	BC2	279.94±15.10	10.67±7.65	BDL	32.23	0.09	0.12
3	BC3	423.21±14.80	11.11±3.05	215.88±13.25	352.41	0.95	0.98
4	BC4	125.04±28.45	6.68±2.50	327.78±6.90	485.03	1.31	1.33
5	BC5	250.89±18.71	15.99±9.00	205.71±24.2	329.47	0.89	0.93
	Mean	**236.95±17.87**	**15.95±6.11**	**192.91±13.96**	**254.88**	**0.69**	**0.93**

BDL = below detectable limit

Table 8: Radiological risk parameter estimated for fruit juice

	Annual Effective dose (mSvy^{-1})				**Excess Lifetime Cancer risk x 10^{-3}**			
Sample Code	**Infant**	**Child**	**Teenager**	**Adult**	ELCR Infant	ELCR Child	ELCR Teen	ELCR Adult
FJ1	5.756	1.308	4.079	0.481	20.147	4.579	14.28	1.683
FJ2	5.606	1.275	3.96	0.467	19.622	4.464	13.861	1.634
FJ3	5.293	1.206	3.753	0.445	18.525	4.223	13.135	1.559
FJ4	0.41	0.101	0.311	0.0447	1.434	0.354	1.088	1.56
FJ5	0.089	0.026	0.115	0.0225	0.314	0.092	0.403	0.0786
Mean	**3.431**	**0.783**	**2.444**	**0.292**	**12.01**	**2.742**	**8.553**	**1.303**

DISCUSSION

The measured specific activities of ^{226}Ra, ^{232}Th and ^{40}K detected in the samples of fruit juice, toothpaste, face powder, soap/detergent powders and body cream samples were summarized in Tables 3-7. It can be noticed that the ^{226}Ra activity concentrations detected in most of the fruit juice samples varied from 0.48 ± 6.21 Bq/l to 35.48 ± 10.19 Bq/l with an average value of 14.21 ± 6.28 Bq/l, for ^{232}Th, the measured specific activity ranged from Bdl to 382.03 ± 6.53 Bq/l with an average value of 282.29 ± 6.07 Bq/l and for ^{40}K from 193.78 ± 25.20 Bq/l to 488.07 ± 14.00 Bq/l with an average value of 328.73 ± 19.08 Bq/l. The highest activity concentration of ^{226}Ra was observed in FJ5 (Tiger nut sample, made in Nigeria) which is higher than the recommended limit 10 Bq/l reported by UNSCEAR (2008), but other samples were within recommended limit. The highest activity concentration of ^{232}Th and ^{40}K were observed in FJ1 (Citron sample, made in Nigeria) and FJ4 (Yoghurt sample, made in Sri lanka) respectively, which were much higher than the recommended limit (1 and 10 Bq/l) for ^{232}Th and ^{40}K respectively, reported by UNSCEAR (2008). The result obtained in this work compared well with the work done by Adeniji *et al*., (2013) which reported average specific activity values for ^{226}Ra, ^{228}Ra and ^{40}K, in bottled fruit juice of 16.44 ± 5.91, 13.64 ± 3.99 and 163.21 ± 49.00 Bq/kg respectively. There is need for caution in the consumption of the juices with high concentration.

Potassium recorded the highest average specific activity in all the fruit juice samples and hence will have the highest contribution to ingestion doses to the consumers. However, potassium is the key element in regulating many body functions such as digestion, heart rate and water content of cells (Adeniji et al., 2013). For this reason, potassium content of the body is held constant by metabolic processes, although some variability between men and women and with age has been observed. Activity concentration of ^{232}Th in all the fruit juice is extremely high compared to low values obtained by Adeniji et al., (2013) in bottled fruit juice. The variation could be due to difference in the fruit plant used in making the juice. This high activity concentration of 232Th will lead to internal exposure for the consumers which ARE likely to cause an increased chance of developing lung diseases and cancer of the lung or pancreas many years after being exposed. Changes in the genetic material of body cells have also been shown to occur in workers who breathed thorium dust (ATSDR, 1990).

The measured specific activities of ^{226}Ra, ^{232}Th and ^{40}K detected in the samples of toothpaste are presented in Table 4. The activity concentration of ^{226}Ra in toothpaste sample varied from 2.69 ± 1.10 Bq/kg to 31.05 ± 13.20 Bq/kg with an average value of 11.47 ± 4.50 Bq/kg, for ^{232}Th the measured specific activity ranged from 201.17±25.32 Bq/kg to 532.35 ± 24.91 Bq/kg with an average value of 336.37 ± 16.09 Bq/kg and for ^{40}K from 184.16 ± 24.40 Bq/kg to 475.49 ± 12.20 Bq/kg with an average value of 349.45 ± 18.05 Bq/kg. The highest activity concentration of ^{226}Ra was observed in TP3 (Fluoride paste sample, made in Nigeria) which is higher than the recommended limit (32 Bq/kg) reported by UNSCEAR (2008), but other samples were within recommended limit. The highest activity concentration of ^{232}Th and ^{40}K were observed in TP5 (Triple protection sample, made in Nigeria) and TP2 (Pro-Health sample, made in Nigeria) respectively, which were much higher than the recommended limit (30 and 400 Bq/kg) for ^{232}Th and ^{40}k respectively, reported by UNSCEAR (2008). The activity concentration of ^{226}Ra is relatively higher than the ^{226}Ra content in toothpaste from Iraq market obtained by Mahdi *et al*., (2014). Exposure to high levels of radium over a long period can lead to death and other severe health problems. High levels of radium can cause cancer (especially bone cancer), anemia, fractured teeth and cavities, and cataracts (Delware Health and Social Services, 2015).

The measured specific activities of ^{226}Ra, ^{232}Th and ^{40}K detected in the samples of face powder samples are presented in Table 5. The activity concentration of ^{226}Ra in face powder sample varied from (8.90 ± 6.03) Bq/kg to (27.95 ± 5.70) Bq/kg with an average value of (18.65 ± 6.94) Bq/kg, for ^{232}Th the measured specific activity ranged from (271.26±13.60) Bq/kg to (388.81 ± 16.60) Bq/kg with an average value of (341.56 ± 18.24) Bq/kg and for ^{40}K from

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(184.16 ± 24.40) Bq/kg to (475.49 ± 12.20) Bq/kg with an average value of (349.45 ± 18.05) Bq/kg. The highest activity concentration of ^{226}Ra was observed in FP2 (quality powder sample) (made in Nigeria). The highest activity concentration of ^{232}Th and ^{40}K were observed in FP4 (Antiseptic absorbent sample).

The measured specific activities of ^{226}Ra, ^{232}Th and ^{40}K detected in the samples of detergent powders were summarized in Table 6. It can be noticed that the ^{226}Ra activity concentrations detected in most of samples vary between 5.35 ± 10.91 Bq/kg to 34.59 ± 14.80 Bq/kg with an average value of 15.70 ± 6.984 Bq/kg, for ^{232}Th the measured specific activity ranged from 162.76 ± 10.62 Bq/kg to 495.05 ± 9.54 Bq/kg with an average value of (286.13± 2.438) Bq/kg and for ^{40}K from 201.52 ± 17.02 Bq/kg to 585.85 ± 11.50 Bq/kg with an average value of 423.79 ± 22.73 Bq/kg. The highest activity concentration for ^{226}Ra was observed in SD4 (Quick action sample) (made in Sri-Lanka) which is slightly higher than the recommended limit (32 Bq/kg) reported by UNSCEAR (2008), but other samples were lower than recommended limit. The highest activity concentration for ^{232}Th and ^{40}K were observed in SD2 (medicated sample) (made in China) and SD1 (complexion sample) (made in London) respectively, which were much lower than the recommended limit (35 and 400 Bq/ kg) for ^{232}Th and ^{40}k respectively, reported by UNSCEAR (2008). The results obtained in this work are higher than the results obtained by Ali *et al.,* (2014) in detergents from Iraq market. The measured specific activities of ^{226}Ra, ^{232}Th and ^{40}K in the samples of body cream are presented in Table 7. The mean activity concentration of ^{226}Ra, ^{232}Th and ^{40}K were 15.95±6.77, 192.91±13.96 and 236.95±17.80 Bq/kg. The high values of thorium in body cream samples might lead to skin cancer since the skin absorbed the cream rich in thorium. Studies have shown that when improperly injected, medical thorium could cause cancer, fibrosis, nerve damage, pain and blood vessel changes in those areas where thorium had leaked out of the blood vessel (ATSDR, 2014).

The calculated Radium equivalent activities values for all the consumer product samples are shown in Tables 3-7. The mean values of Raeq in fruit juice, toothpaste, face powder, soap/detergent and body cream samples were 362.46, 519.38, 532.16, 460.31 and 254.88 Bq/kg. It is observed that the Raeq values for all the studied samples are higher than the recommended maximum value of 370 Bq/kg (OECD, 1979) except fruit juice and body cream samples. The annual effective dose and excess lifetime cancer risk were estimated in fruit Juice samples only for four age brackets and presented in Table 8. It was obvious that infant and teenagers will be more affected from drinking fruit juice. It therefore call for moderate consumption of fruit juices by children and tenagers as their patronage is a mark of social status in Nigeria. The annual effective dose for infants, children, teenagers and adults are 3.431, 0.783, 2.444 and 0.292 mSvy^{-1}. The values for infant and teenagers exceeded the safe limit of 1.0 mSvy^{-1} stipulated by ICRP, (2008). The excess lifetime cancer risk exceeded the safe limit in all the entire bracket.

The mean values of external hazard index for all the samples (Fruit juice, toothpaste, face powder, soap/detergent and body cream) were 0.98, 1.40, 1.44, 1.08 and 0.69 respectively while that for internal hazard indices are 1.02, 1.43, 1.49, 1.12 and 0.93 respectively. These values of H_{ex} except for fruit juice and body cream are higher than the acceptable value of unity (ICRP, 2007). The internal exposure to ^{222}Rn and its radioactive progeny is controlled by the internal hazard index (H_{in}). The values of internal hazard index for all the samples exceeded the safe value of unity except for body cream samples. These higher values of the radiological hazard indices have shown that these consumer products may at long term exposure cause health risk to the consumers.

CONCLUSIONS

In the present study activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K for all the consumer product samples collected from Port Harcourt markets have been evaluated. The mean values of activity concentrations of ^{226}Ra and ^{40}K in all samples except fruit juice samples were lower than the maximum recommended values of 30, 35 and 400 Bq/kg as in UNSCEAR, (2008). The activity concentration of ^{232}Th in all the consumer product sampled was higher than the safe limit.

Also, it is found the average of Radium equivalent activities was determined to be lower than the recommended maximum level of radium equivalent of 370 Bq/kg by OECD 1979 for fruit juice and body cream samples but higher than the recommended safe value in toothpaste, face powder and soap/ detergent samples, while the averages for both the external and internal hazard indices exceeded a unity, the limit recommended by ICRP, 2000 except in body cream samples. The annual effective doses and excess lifetime cancer risk estimated from fruit juice samples exceeded the dose limit for infants and teenagers. Infants and teenagers that ingest the fruit juice may have long term radiation related health risks. Consumer of all these products studied are likely to be exposed to have high level of ^{232}Th from the products which in long term may lead to radiation related health risks mentioned earlier.

Based on the results obtained in this work, producers of consumer products should minimized the use of thorium based raw materials in order to reduce human exposure to minimal level. Also tiger nut farmers should avoid the excessive use of fertilizers in their faming practice to reduce radionuclide transfer ratio since tiger nut recorded the highest values of all the radionuclides identified.

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