Journal of Physical Chemistry & Biophysics

Akinyose et al., J Phys Chem Biophys 2017, 8:1
DOI: 10.4172/2161-0398.1000262

Research Article Open Access

Radiological Impacts of Natural Radioactivity in Locally Produced Tobacco Products in Oyo State, Nigeria

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Rec date: November 29, 2017; **Acc date:** December 24, 2017; **Pub date:** December 28, 2017

Abstract

Radionuclides are found naturally in air, water and soil. They are even found in vegetation, consumer products and in human body. Everyone on the planet is exposed to some background level of ionizing radiation through external exposures that occurs as a result of irradiation, and internal exposures that occurs as a result of ingestion and inhalation. Studies have shown that tobacco contains minute quantities of radioisotopes from uranium and thorium-decay series which are radioactive and carcinogenic. Tobacco product increases both external and internal exposure due to these radioisotopes. In fact, tobacco products have been considered to be one of the most significant causes of lung cancer. Owing to the large-scale consumption of tobacco in Nigeria at the present time, locally produced tobacco products in Nigeria were collected from the market and the naturally-occurring ^{238}U and ^{232}Th decay series, as well as non-series decay ^{40}K in these products were measured using γ-ray spectrometer. The radiological impacts of the radionuclides in these products were assessed from their specific activities. The average values of the absorbed dose rate were 19.72 and 17.59 nGy h^{-1} for snuff and cigarette products respectively. The average values of the effective doses due to daily inhalation of smoke by consumers from one (1) stick of cigarette and one (1) wrap of snuff products were 66.62 and 592.32 μSv yr^{-1} respectively. Similarly, the values of the radium equivalent activity index for snuff and cigarette samples were 40.95 and 38.95 Bq kg^{-1} respectively. Also, the external radiation hazard index was 0.12 and 0.11 for snuff and cigarette samples respectively while the internal radiation hazard index was 0.17 and 0.15 for the two samples respectively. The average excess lifetime cancer risk (× 10^{-3}) values for daily inhalation of smoke from one (1) stick of cigarette and one (1) wrap of snuff were 0.23 and 2.07 × 10^{-3} respectively. The estimated values of some of these parameters were found to be lower than the recommended limit by UNSCEAR (2000). However, the effective dose poses a serious health risk to addicted consumers of the product and passive smokers in the environment when three (3) or more wraps of snuff and one (1) or more packs of cigarette products are consumed daily. The mean excess lifetime cancer risks values estimated were also much higher than the recommended limits by UNSCEAR (2000). This then makes the risk of suffering cancer and other radiation injuries to be high.

Keywords: Radioactivity; Radiological impact parameters; Tobacco; Cigarette; Snuff; Cancer; Radiation injury

Introduction

Tobacco is green leafy plant grown in warm climate. It belongs to the genus Nicotiana and species Tabacum. After the leaves are harvested, they are then dried, ground up, and used in different ways: They can be smoked in a cigarette (the most consumed product in Nigeria), pipe, or cigar. They can also be chewed in the mouth (called smokeless tobacco or chewing tobacco) or sniffed through the nose (called snuff) [1]. Tobacco has been well known with its nicotine content which makes the product addictive. More than 4,000 chemicals in which some are carcinogens have been isolated from tobacco. Hydrocarbons (aromatic and aliphatic), aldehydes, ketones, heavy metals including arsenic, non-radioactive lead, radionuclides among others) had been said to be present in tobacco [2-4]. This research work focused on the radioactive components found in tobacco and their likely contributions to health.

Whether the source of radiation is natural or man-made, whether it is a small dose of radiation or a large dose, there will be some biological effects. Radiation causes ionizations of atoms which may affect molecules which in turns affect cells. Affected cells also affect the tissue which in turns affect organs and generally affect the whole body. Biological effects of radiation can occur as a result of exposure to high doses of radiation over short periods of time producing acute or short-term effects (deterministic effect) or exposure to low doses of radiation over an extended period of time producing chronic or long-term effects (stochastic effect). Exposure to low doses of radiation causes Genetic effect (effect suffered by the offspring of the individual exposed) and Somatic effect. This is the effect suffered primarily by the exposed individual. Cancer is the primary result and it is sometimes called the carcinogenic effect [5].

Consumption of tobacco products may increase the internal intake and radiation dose due to these radioisotopes [1,6-10]. Though, this dose is low, but persisted consumption of these products makes it to be accumulated over an extended period of time in the body and can lead to chronic or long-term effects (stochastic effect). It may not cause an immediate problem to the body organs but spreads over a long period of time. Also in a number of studies, inhalation of some naturally occurring radionuclides via smoking has been considered to be one of the most significant causes of lung cancer [11]. Tobacco products damage nearly every organ in the human body and accounts for some 30 per cent of all cancers death [12]. Unlike vegetables that before consumption are always washed, tobacco leaves are directly dried in the tobacco curing process without washing and this makes tobacco product to retain almost all the contents present in the leaves [13].

Tobacco products include the smoked and the smokeless tobacco. The smoked tobacco includes: Bidis, Cigarettes, Cigars, Cigarillos, Little Cigars, Dissolvable tobacco, Electronic Cigarette or E- cigarette, Hookah, Kreteks and Pipe while the smokeless tobacco includes the Snuff and the chewing or leaking tobacco. Among all these products, cigarettes and smokeless tobacco (snuff) are the products locally produced in Nigeria.

A cigarette is a combination of cured and finely cut tobacco, reconstituted tobacco and other additives rolled or stuffed into a paper wrapped cylinder. Many cigarettes have a filter on one end. Studies have proven that smoking cigarettes causes cancers of the bladder, oral cavity, pharynx, larynx (voice box), esophagus, cervix, kidney, lung, pancreas, and stomach, and causes acute myeloid leukemia. It also causes heart disease and stroke [14,15].

The two main types of smokeless tobacco are snuff and chewing or leaking tobacco. Chewing tobacco comes in the form of loose leaf or twist. Snuff is finely dried ground tobacco that are in sachets (tea bag-like pouches). Snuffs locally made in Nigeria are powdered dried ground tobacco wrapped in paper or nylon and usually inhaled (sniffed) through the nose. Smokeless tobacco has a significant health risk and is not a safe substitute for smoking cigarettes [14,16,17].

The carcinogenic effects and some other diseases related to these products may be as a result of the radioactive elements that may be present on the leaves before processed to products [18]. All methods of tobacco consumption results in varying quantities of radiation to be absorbed into the consumers bloodstream which can cause radiation injuries such as cancer, ulcer, leukemia and many other diseases over time [19]. Thus, many countries set a minimum smoking age, regulating the purchase and use of tobacco products.

The main routes of radionuclide in tobacco are the fertilizer that farmers use to increase the size of their tobacco crops and trichomes, a sticky, hair-like projection that thickly cover both sides of tobacco leaves [20]. Rain does not wash them away and their existence in tobacco depends on the tobacco origin (how much fertilizers used and natural level of uranium and radium in the soil where the tobacco is grown [6-8,20,21].

Although not everyone who uses tobacco will get cancers, and not everyone that gets cancer uses tobacco, but its consumption over time greatly increases a person's risk. This work is focused on assessing the risk associated to the consumption of tobacco products due to these naturally occurring radionuclides.

Materials and Methods

Sample collection

Smoked (cigarette) and smokeless (snuff) tobacco products were obtained from Agbeni market in Ibadan, Nigeria. This market is a wholesaler's market popularly known as the "mother of markets" in the city of Ibadan, Oyo state, Nigeria. Twelve (12) cigarette samples (Six (6) packets each) of different brands and two (2) snuff samples were bought each from two different shops in the market. At the point of collection of the samples, they thoroughly mixed together to represent a sample from each shop, then carefully labeled and placed in separate polythene bags to avoid cross contamination. The descriptions of the various samples are shown in Table 1. Figure 1 also shows the map of Oyo state identifying the study area.

Sample preparation

The samples were dried at of 105°C in a temperature controlled oven until there was no detectable change in the mass of the sample. Cigarette samples were then thoroughly ground and pulverized to obtain a powder form like snuff samples. Each sample were weighed and sealed for at least 28 days in a clean and uncontaminated air tight radon impermeable plastic container. This was done in order to allow radon and its short-lived progenies to reach secular radioactive equilibrium prior to gamma spectroscopy.

Measurement of measurement

The detector used for the radioactivity measurements is a lead-shielded 76 mm × 76 mm NaI(Tl) detector crystal (Model No. 802 series, Canberra Inc.) coupled to a Canberra Series 10 plus Multichannel Analyzer (MCA) (Model No.1104) through a preamplifier. Its resolution is considered adequate to distinguish the gamma ray energies of interest in this study. Each sealed sample was placed on the shielded NaI(Tl) detector and counted for 18,000 s. The samples containers have the same geometry as that of the IAEA reference sample material. The IAEA-375 soil reference material was used. An empty container of the same geometry and dimension was counted for the same counting time of 18,000 s to determine the background distribution spectrum.

The choice of radionuclides to be detected was predicated on the fact that the NaI(Tl) detector used in this study had a modest energy resolution. Hence the photons emitted by them would only be sufficiently discriminated if their emission probability and their energy were high enough, and the surrounding background continuum is low enough. Therefore, the activity concentration of ^{214}Bi (determined from its 1120 keV and 609 keV γ-ray peaks) were chosen to provide an estimate of ^{226}Ra (^{238}U) in the samples, while that of the daughter radionuclide ^{228}Ac (determined from its 911 keV γ-ray peak) was chosen as an indicator of ^{232}Th. ^{40}K was determined by measuring the 1460 keV γ-rays emitted during its decay. The net area under the corresponding peaks in the energy spectrum was computed by subtracting counts due to compton scattering of higher peaks and other background sources from the total area of the peaks. From the net area, the activity concentrations in the samples were obtained using the following equation:

$$C = \frac{A}{\varepsilon M_s P_\gamma t_c} \quad (1)$$

Where A=the net area of the peak,

ε=efficiency of the detector for radionuclide n,

M_s=dried mass of ashed sample for measurement in kg,

P_γ=gamma emission probability (or branch ratio), and

t_c=counting time.

Uncertainties

Uncertainties in gamma-ray spectrometry could result from the error in the determination of the nuclide specific counting efficiency and the statistical counting errors. These errors were put into

Citation: Akinyose FC, Tchokossa P, Orosun MM, Mark IB, Ochommadu KK, et al. (2017) Radiological Impacts of Natural Radioactivity in Locally Produced Tobacco Products in Oyo State, Nigeria. J Phys Chem Biophys 7: 262. doi:10.4172/2161-0398.1000262

consideration in the determination of radionuclide activity concentration.

S/N	Sample ID	Samples name	Mass of fresh tobacco product (g)	Mass after sieving of dried tobacco product (g)	Longitude	Latitude
SNUFF						
1	AFC1	Snuff A	106.1	105.5	3o5325.05"E	7o2248.52"N
2	AFC2	Snuff B	109.5	108.8	3o5325.00"E	7o2248.23"N
CIGARETTE						
1	AFD1	Pallmall red A	108.9	107.7	3o5325.10"E	7o2248.31"N
2	AFD2	Pallmall red B	105.2	103.4	3o5325.17"E	7o2248.34"N
3	AFE1	London Menthol A	97.7	94.8	3o5325.10"E	7o2248.31"N
4	AFE2	London Menthol B	98.9	96	3o5325.17"E	7o2248.34"N
5	AFF1	London King size A	111.4	110.8	3o5325.10"E	7o2248.31"N
6	AFF2	London King size B	115.2	114.6	3o5325.17"E	7o2248.34"N
7	AFG1	Royal standard A	93.1	91.2	3o5325.10"E	7o2248.31"N
8	AFG2	Royal standard B	94.7	93.5	3o5325.17"E	7o2248.34"N
9	AFH1	Aspen A	101.7	99.2	3o5325.10"E	7o2248.31"N
10	AFH2	Aspen B	102.1	100.7	3o5325.17"E	7o2248.34"N
11	AFI1	Pallmall green A	104.2	102.6	3o5325.10"E	7o2248.31"N
12	AFI2	Pallmall green B	108.5	107.2	3o5325.17"E	7o2248.34"N
Average			103.5	101.8		

Table 1: Tobacco Products Bought from Agbeni Market, Ibadan. *Average of 0.86 g per mass of fresh tobacco in cigarette.

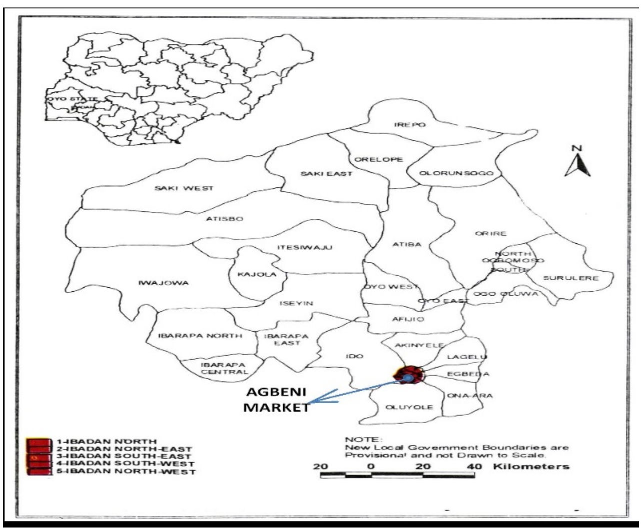

Figure 1: Map of Oyo State Showing the Study Area.

Results and Discussion

Radionuclides concentration

The activity concentration of the radionuclides detected are presented in Table 2 and illustrated in Figure 2. All the radionuclides detected and quantified came from the naturally-occurring ^{238}U and ^{232}Th decay series, as well as non-series ^{40}K. As could be observed from the table, the specific activity concentration of ^{40}K, ^{238}U and ^{232}Th for snuff products ranged between 64.28 ± 20.43 and 74.38 ± 25.20 Bq kg^{-1} (with an average of 69.33 ± 22.82 Bq kg^{-1}), 9.45 ± 3.88 and 25.36 ± 7.51 Bq kg^{-1} (with an average of 17.41 ± 5.70 Bq kg^{-1}), 10.28 ± 4.37 and 18.81 ± 7.22 Bq kg^{-1} (with an average of 14.55 ± 5.80 Bq kg^{-1}) respectively.

For cigarette products, the specific activity concentration of ^{40}K, ^{238}U and ^{232}Th ranged from 40.13 ± 14.23 to 57.53 ± 20.13 Bq kg^{-1} (with an average of 48.37 ± 15.78 Bq kg^{-1}), 8.91 ± 3.41 to 28.56 ± 7.69 Bq kg^{-1} (with an average of 17.52 ± 5.73 Bq kg^{-1}) and 4.90 ± 1.49 to 19.39 ± 8.13 Bq kg^{-1} (with an average of 12.39 ± 4.50 Bq kg^{-1}) respectively.

From this result, it can be noticed that the radioactivity in snuff products was a little bit higher than that of the cigarette products. It can also be noticed that the radioactivity content varies within the same brands of cigarette and also with different brands. This may be attributed to the geographic region where the tobacco (raw material) is grown, the fineness of the tobacco cut, the size and composition of the filter in cigarette product, different manufacturing procedures and age of the tobacco product [22,23].

Absorbed dose rate from tobacco products

The absorbed dose is the concentration of energy deposited in tissue as a result exposure. It tells us the energy absorbed by human tissue. Calculating the absorbed dose rate is the first major step to evaluate radiation injuries. With regard to any radiation injury, the radiological and clinical effects are directly related to the absorbed dose rate [24]. The external absorbed dose rate D (nGy h^{-1}), at a height of 1 m above the ground surface due to activity concentration of ^{238}U, ^{232}Th and ^{40}K was calculated using equation 2 [25],

$$D=C_U A_U+C_{Th} A_{Th}+C_K A_K \quad (2)$$

Where A_U, A_{Th}, A_K are the radioactivity concentration in Bq kg^{-1} and c_U, c_{Th}, and c_K are dose conversion factors which are 0.462, 0.604 and 0.042 for ^{238}U, ^{232}Th and ^{40}K respectively [26].

S/N	ID	SNUFF								
		K-40 (Bq kg^{-1})	U-238 (Bq kg^{-1})	Th-232 (Bq/kg)	D (nGy h^{-1})	E (μSv y^{-1})	ELCR (× 10^{-1})	Raeq (Bq kg^{-1})		
1	AFC1	64.28 ± 20.43	25.36 ± 7.51	10.28 ± 4.37	20.61	450.47	1.58	42.81		
2	AFC2	74.38 ± 25.20	9.45 ± 3.88	18.81 ± 7.22	18.83	734.17	2.57	39.1		
	MEAN	69.33 ± 22.82	17.41 ± 5.70	14.55 ± 5.80	19.72	592.32	2.07	40.95		
		CIGARETTE								
	ID				D (nGy h^{-1})	E (μSv y^{-1})	ELCR (× 10^{-1})	E^* (μSv yr^{-1})	$ELCR^*$ (× 10^{-3})	R^{aeq} (Bq kg^{-1})
3	AFD1	49.81 ± 12.47	28.56 ± 7.69	9.49 ± 3.45	21	111.38	0.39	55.69	0.19	45.97
4	AFD2	42.52 ± 15.69	14.43 ± 5.18	11.04 ± 3.61	15.11	118.05	0.41	59.03	0.21	33.49
	MEAN	46.17 ± 14.08	21.50 ± 6.44	10.27 ± 3.53	18.06	114.72	0.4	57.36	0.2	39.73
5	AFE1	56.83 ± 19.95	19.04 ± 6.49	8.34 ± 3.42	16.2	94.18	0.33	47.09	0.16	35.34
6	AFE2	46.01 ± 16.01	17.87 ± 5.98	7.18 ± 2.52	14.51	81.98	0.29	40.99	0.14	31.68
	MEAN	51.42 ± 17.98	18.46 ± 6.24	7.76 ± 2.97	15.36	88.08	0.31	44.04	0.15	33.51
7	AFF1	40.13 ± 14.23	11.78 ± 4.68	4.90 ± 1.49	10.08	55.7	0.19	27.85	0.1	21.88
8	AFF2	44.32 ± 13.12	13.85 ± 5.82	6.78 ± 2.76	12.34	75.56	0.26	37.78	0.13	26.96
	MEAN	42.23 ± 13.69	12.82 ± 5.25	5.84 ± 2.13	11.21	65.63	0.23	32.82	0.11	24.42
9	AFG1	53.62 ± 19.84	12.77 ± 5.79	18.22 ± 6.81	19.14	188.06	0.66	94.03	0.33	42.95
10	AFG2	57.53 ± 20.13	28.50 ± 6.88	15.34 ± 5.19	24.83	169.21	0.59	84.61	0.3	54.87
	MEAN	55.58 ± 19.99	20.64 ± 6.34	16.78 ± 6.00	21.99	178.63	0.63	89.32	0.31	48.91
11	AFH1	44.14 ± 13.02	23.06 ± 7.31	12.57 ± 3.43	20.09	138.47	0.48	69.24	0.24	44.43
12	AFH2	53.26 ± 17.13	8.91 ± 3.41	19.08 ± 7.87	17.86	194.2	0.68	97.1	0.34	40.3
	MEAN	48.70 ± 15.08	15.99 ± 5.36	15.83 ± 5.65	18.97	166.34	0.58	83.14	0.29	42.36
13	AFI1	42.70 ± 12.31	16.49 ± 5.31	19.39 ± 8.13	21.11	201.9	0.71	100.95	0.35	47.51
14	AFI2	49.57 ± 15.35	14.93 ± 4.13	16.28 ± 5.31	18.8	170.19	0.6	85.1	0.3	42.03
	MEAN	46.14 ± 13.83	15.71 ± 4.72	17.84 ± 6.72	19.95	186.05	0.65	93.03	0.33	44.77
	OCM	48.37 ± 15.78	17.52 ± 5.73	12.39 ± 4.50	17.59	133.24	0.47	66.62	0.23	38.95

Table 2: Activity Concentration of Radionuclides and Radiological Impact (Bq kg^{-1}) in Tobacco Products. E^* and $ELCR^*$ are the annual effective doses and excess lifetime cancer risks for smokers inhaling 50% of cigarette smoke respectively. OCM=Overall cigarette mean.

The results of the absorbed dose rates D (nGy h^{-1}) in air at 1 m above the ground level are presented in Table 2 and illustrated in Figure 3. The values ranged between 18.83 and 20.61 nGy h^{-1} with an average of 19.72 n Gy h^{-1} and 10.08 to 24.83 nGy h^{-1} with an average of 17.59 nGy h^{-1} for snuff and cigarette products respectively. The absorbed dose rate was found to be higher in snuff than in cigarette.

All the calculated values of the absorbed dose rate were lower when compared to the recommended limit of 57 nGy h^{-1} [26]. Hence, the products do not pose a serious health risk, but the radioactivity contents have to be monitored not only because of the persistent usage of phosphate fertilizer by farmers on soils where the raw material (tobacco leaf) is produced from but also for its long-term effect, due to accumulation.

Annual effective dose e (μsv yr^{-1}) from tobacco products

The effective dose is a quantity that takes the damaging properties of different types of radiation into account. Absorbed dose tells us the energy deposit in a small volume of tissue and effective dose addresses the impact a type of radiation will have on all organs of the body. It is the tissue-weighted sum of the equivalent doses in all specified tissues and organs of the body and represents the stochastic health risks to the whole body. It takes into account the type of radiation and the nature of each organ or tissue being irradiated, and enables summation of organ doses due to varying levels and types of radiation, both internal and external, to produce an overall calculated effective dose. It is the sum of the effective dose over a year.

The annual effective dose (μSv y^{-1}) due to inhalation of snuff products: The annual effective dose due to inhalation of snuff products was calculated using equation 3 [6,8]:

$$E_s = A(\text{Bq kg}^{-1}) \times M(\text{kg y}^{-1}) \times DCF \quad (3)$$

The annual effective dose (μSv y^{-1}) due to inhalation of cigarette products: About 75% of the radioisotope in the cigarette tobacco will be contained in the cigarette smoke, which is partially inhaled and deposited in body tissues. 25% will also be retained in the cigarette filter and ash [6,27,28]. Therefore, the annual effective dose from cigarette smoke was calculated using equation 4.

$$E_c = 0.75 \times A(\text{Bq kg}^{-1}) \times M(\text{kg y}^{-1}) \times DCF \quad (4)$$

At least 50% of the cigarette smoke was said to be inhaled by primary smoker [8,28]. Therefore, the annual effective dose inhaled from cigarette smoke by primary smokers was calculated using equation 5,

$$E_{cp} = 0.5 \times 0.75 \times A(\text{Bq kg}^{-1}) \times M(\text{kg y}^{-1}) \times DCF \quad (5)$$

Where E_s is the annual effective dose for snuff;

E_c is the annual effective dose for cigarette smoke;

E_{cp} is the annual effective dose due to inhalation of cigarette smoke by primary smokers:

A is the activity concentration of radionuclide;

M is the consumption rate per year and DCF is the standard dose conversion factor.

The most recent dose conversion coefficients for the case of inhalation for adults are 2.9×10^{-6}, 4.5×10^{-5}, and 2.1×10^{-9} Sv Bq^{-1} for ^{238}U, ^{232}Th and ^{40}K respectively (ICRP 119, 2012).

Locally made snuffs in Nigeria are sold in wrapping papers or nylons. Average mass of one (1) wrap of snuff is 2.3 g and that of fresh tobacco per stick of cigarette is 0.86 g. Therefore, the annual consumption rate of consuming one (1) wrap and one (1) stick of snuff and cigarette daily were estimated to be 0.840 and 0.314 kg y^{-1} respectively.

The values of the annual effective dose due to sniffing of one (1) wrap of snuff daily ranged between 450.47 and 734.17 μSv yr^{-1} with an average of 592.32 μSv yr^{-1}. Also, the annual values of the annual effective dose of the smoke from one (1) stick of cigarette daily ranged from 55.70 to 201.90 μSv yr^{-1} with an average of 133.24 μSv yr^{-1}. Similarly, the annual effective dose for primary smokers inhaling 50% of the cigarette smoke from one (1) stick of cigarette daily ranged from 27.85 to 100.95 μSv yr^{-1} with an average of 66.62 μSv yr^{-1} [8,28]. This dose was low when compared with the average worldwide exposure to natural radiation sources which is 2400 μSv y^{-1} and especially the part due to inhalation which is 1260 μSv y^{-1} [26].

The effective doses were found to be higher in snuff than in cigarettes. All the calculated values were found to be lower than the recommended limit of 1260 μSv y^{-1} [26], and hence do not pose serious health risk. However, it is to be noticed that all the calculated values above were for one wrap of snuff and one stick of cigarette. It will be an under-estimation to consume just one wrap of snuff and one stick of cigarette daily for addicted consumers as tobacco contains nicotine which makes the product to be addictive. Also, these products are readily available in our community and are not expensive.

Therefore, the dose received from cigarette and snuff product will be a multiplication factor of the consumption rate. Consuming three wraps of snuff and one pack of cigarette daily will result in annual effective doses of 1776.96 and 1332.41 μSv y^{-1} respectively. These values are higher than the recommended limit of 1260 μSv y^{-1} [26]. This therefore increases the internal intake of ^{40}K, ^{238}U, and ^{232}Th which are gamma emitters. When these radionuclides are inhaled, they are deposited in the lung tissues and other critical organs within the body; which then contribute to an increase in the internal radiation dose and in the number of lung cancer and other related radiation diseases incidences observed among consumers of tobacco products.

Radium equivalent activity index (Ra_{eq}) for tobacco products: This allows a single index or number to describe the gamma output from different mixtures of ^{238}U, ^{232}Th and ^{40}K in a material. It was calculated using equation 6 by UNSCEAR, 2000:

$$Ra_{eq} = A_U + 1.43\, A_{Th} + 0.077 A_K \quad (6)$$

Where AU, ATh and AK are the radioactivity concentration in Bq kg^{-1} of ^{238}U, ^{232}Th and ^{40}K respectively.

The values of the radium equivalent activity index, Ra_{eq} (Bq kg^{-1}) for tobacco product ranged between 39.10 and 42.81 Bq kg^{-1} with an average of 40.95 Bq kg^{-1} for snuff and from 21.88 to 54.87 Bq kg^{-1} with an average of 38.95 Bq kg^{-1} for cigarette products. These values were found to be lower than the recommended limit of 370 Bq kg^{-1} [26], and hence do not pose a serious health risk.

Excess Lifetime Cancer Risk (ELCR) for tobacco products: The Excess Lifetime cancer risk (ELCR) was calculated using the below equation [25]:

$$ELCR = AEDE \times DL \times RF \quad (7)$$

Where, AEDE is the annual equivalent dose equivalent, DL is the average duration of life (estimated to 70 years), and RF is the Risk Factor (Sv^{-1}), i.e., fatal cancer risk per Sievert. For stochastic effects, ICRP uses RF as 0.05 for public [25]. Average value of ELCR is given as 0.2×10^{-3} [29].

The estimated values of the excess life time cancer risk ($\times 10^{-3}$) from one (1) wrap of snuff daily ranged between 1.00 and 1.65 with an average of 1.32 (Figure 4). Similarly, it ranged from 0.20 to 0.71 with an average of 0.47 for cigarette smoke from one (1) stick. The excess lifetime cancer risk ELCR ($\times 10^{-3}$) for smokers inhaling 50% of the cigarette smoke from one (1) stick of cigarette daily ranged between 0.10 to 0.36 with an average of 0.24 [8,28] (Figure 5).

It is important to note that all the values calculated were higher than the recommended limit of 0.2×10^{-3} [26]. This poses a serious cancer risk to all the consumers and the passive smokers in the environment.

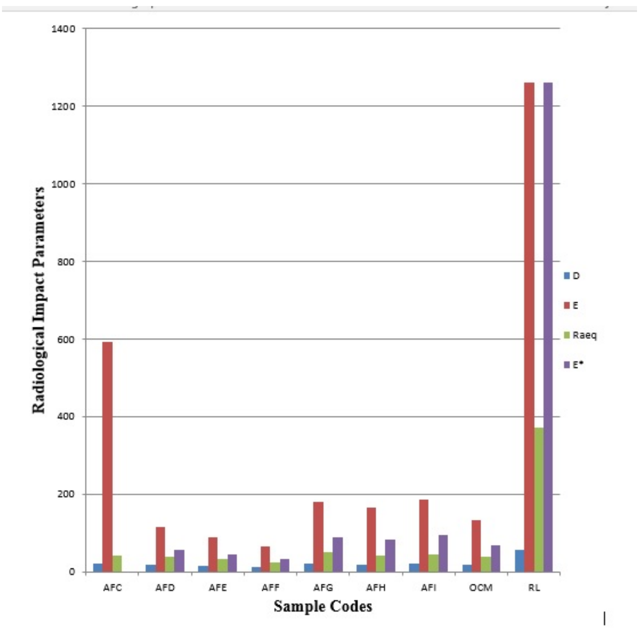

Figure 2: Radiological impact parameters for tobacco products. D is the absorbed dose rate; E is the equivalent dose for 100% of the smoke; Ra_{eq} is the radium equivalent activity index and E^* is the equivalent dose for 50% of the smoke inhaled by primary smoker.

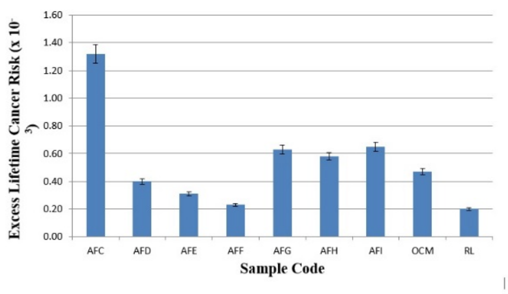

Figure 3: Excess Lifetime Cancer Risk ($\times 10^{-3}$) for Tobacco Product. OCM=Overall cigarette mean; RL=Recommended limit by UNSCEAR (2000).

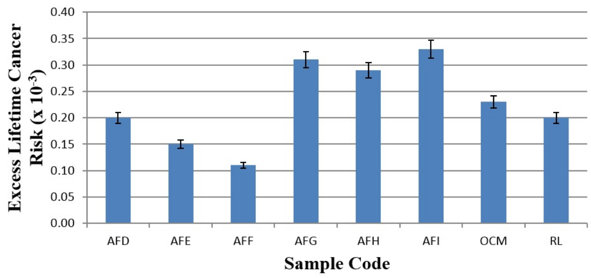

Figure 4: Excess Lifetime Cancer Risk ($\times 10^{-3}$) for Primary Smokers of Cigarette. RL=recommended limit by UNSCEAR (2000) OCM=Overall cigarette mean.

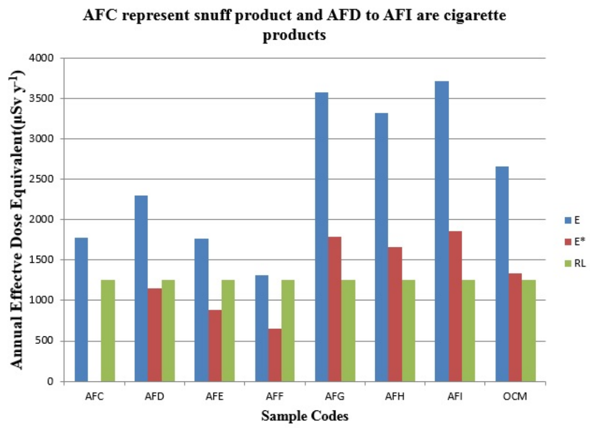

Figure 5: Annual effective doses equivalent ($\mu Sv\ y^{-1}$) for Sniffing 3 wraps of snuff (AFC) and 1 pack of cigarette daily (AFD-AFI). RL is the recommended limit by UNSCEAR 2000. E is the annual effective dose for sniffing 3 wraps of snuff daily (AFC) and annual effective dose for inhaling 100% of the smoke from 1 pack of cigarette daily (AFD-AFI). E^* is the annual effective dose received by primary smoker inhaling 50% of smoke from 1 pack of cigarette daily (AFD-AFI). OCM is the overall mean of the annual effective received from inhaling 50% (for primary smokers) and 100% (all the smoke) of the smoke from cigarette.

Conclusion

The radioactivity content in snuff products was a little bit higher than that of the cigarette products. Furthermore, the radioactivity content varies within the same brands of cigarette and also with different brands. The estimation of some radiological impact parameters which are the absorbed dose rate, annual effective dose (due to inhalation of one (1) stick of cigarette and one (1) wrap of snuff), radium equivalent activity and radiation hazard indices were found to be lower than their respective recommended limit. However, the effective dose poses a serious health risk to addicted consumers and passive smokers in the environment when three (3) or more wraps of snuff and one (1) or more packs of cigarette products are consumed daily. The excess lifetime cancer risks values estimated were also much higher than the recommended limits by UNSCEAR [26]. This poses a serious cancer risk and some other radiation injuries to the consumers and passive smokers in the environment.

It can then be concluded that numerous variables such as the geographic region where the tobacco (raw material) is grown, the fineness of the tobacco cut, the size and composition of the filter, different manufacturing procedures, age of the products and sniffing or smoking habits govern the degree of exposure via the pathway of tobacco.

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