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Radionuclide Analysis of Locally Processed Snuff Tobacco Consumed in Benue State

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ABSTRACT

Radionuclide analysis of locally processed snuff tobacco consumed in Benue state was carried out using a lead-shielded NaI(TI) detector crystal (Model No. 802 series, Canberra Inc.) coupled to a Canberra series 10 plus Multichannel Analyzer (MCA) (Model No. 1104) through a preamplifier. The detector measured the radionuclide activity concentrations of locally processed snuff samples collected from the selected Local Government Areas (LGAs) of the state. The results showed that the average values of activity concentrations ($Bqkg^{-1}$) of ^{40}K, ^{238}U and ^{232}Th in the analyzed snuff samples were 1292.86 ± 63.73, 22.57 ± 2.65 and 8.26 ± 0.48 $Bqkg^{-1}$ respectively. In addition, a control sample (an additives-free snuff) was used. The activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the additives-free snuff sample were 617.73 ± 30.93 $Bqkg^{-1}$, 26.49 ± 3.05 $Bqkg^{-1}$ and 4.06 ± 0.23 $Bqkg^{-1}$ respectively, whereas the activity concentrations of a snuff sample made with additives (S5) that shared tobacco leaves of same source (plants) with the additives-free snuff (A5) during their processing were 565.05 ± 28.14 $Bqkg^{-1}$, 28.86 ±3.61 $Bqkg^{-1}$ and 4.28 ± 0.25 $Bqkg^{-1}$ for ^{40}K, ^{238}U and ^{232}Th respectively. Meanwhile, the mean value of radium equivalent activity obtained for the snuff products was 133.93 $Bqkg^{-1}$ and thus found to be lower than the UNSCEAR recommended limit of 370 $Bqkg^{-1}$. The estimated average value of annual effective dose (μSvy^{-1}) was 369.14 for inhaling 1 wrap of snuff daily, and was also found to be lower than the UNSCEAR recommended limit of 1260 μSvy^{-1}. However, consuming 4 wraps of snuff daily would result to an annual effective dose of 1476.56 μsvy^{-1}. This value was therefore found to be higher than the recommended limit of 1260 μSvy^{-1}. Furthermore, the estimated excess lifetime cancer risk averaged 1.29×10^{-3} for inhaling 1 wrap of snuff daily and was thus seen to be higher than the UNSCEAR recommended limit of 0.2×10^{-3}.

Keywords:
Tobacco,
Snuff,
Radionuclides,
Effective dose,
Cancer risk.

INTRODUCTION

Tobacco is an agricultural product processed from the fresh leaves of plants in the genus Nicotiana and species Tabacum with high nicotine content which makes the products to be addictive (Agba *et al.,* 2012). Archeological studies suggest the use of tobacco in around first century BC, when Maya people of central America used tobacco leaves for smoking, in sacred and religious Ceremonies. It then started spreading as far as high up to the Missisippi valley with the Maya community migrating from down south of America, between 470 and 630 AD. Gradually, it was then adopted by neighboring and native tribes. Today, tobacco is used in various forms in different parts of the world (Mishra and Mishra, 2013).

Tobacco contains naturally-occurring radionuclides from ^{238}U and ^{232}Th decay series, as well as non-series ^{40}K (Akinyose *et al.,* 2018). The two main sources of radionuclides into tobacco are due to root uptake from the soil and phosphate fertilizers that farmers use for the tobacco cultivation (Mwalongo *et al.*, 2023). The other source of radionuclides into tobacco is through the trichomes of tobacco leaves. Trichomes are sticky, hair-like projections that thickly cover both sides of tobacco leave (EPA, 2022). Tobacco products can be grouped into two forms; these include smoked tobacco products and smokeless tobacco products (IARC, 2007).

Snuff is a generic term for fine-ground smokeless tobacco product (George *et al.*, 2010). In Benue state, snuff is made from locally dried tobacco leaves, mixed with potash or trona (locally called kanwa) and little water. It is grinded into powdered form using grinding machine or stones, or pounded with pestle and mortal. Snuff is then wrapped in nylon for sales and is usually inhaled (sniffed) lightly after a pinch of snuff is either held pinched using index or middle finger, or held by a specially made "snuffing" device. Based on the interviews conducted by the researcher for this study, this is the general method of snuff production in Benue state.

The inhalation of tobacco products increases internal intake and radiation dose due to the natural occurring radionuclides from ^{238}U and ^{232}Th decay series, and non-series ^{40}K present in tobacco products (Belafrites *et al.*, 2019). All methods of tobacco consumption result in varying quantities of radiation to be absorbed into the consumer's blood stream which can cause radiation injuries such as cancer, ulcer, leukemia and many other diseases over time (Ponte, 1986). Smokeless tobacco (snuff) particularly causes oral cancer, esophageal cancer and pancreatic cancer (IARC, 2007). Since snuff tobacco has a significant health risk, it is not a safe substitute for cigarettes (WHO, 2022).

Regardless of its health consequence, tobacco plays a vital role in a nation's economy. The cultivation of tobacco, along with the manufacturing and distribution of tobacco products, is essential for economic stability. Without these activities, a country could face devastating economic repercussions. The economic contributions from tobacco include providing jobs for farmers and employees, generating tax revenues for governments, yielding significant profits for tobacco companies, and for some nations, contributing to foreign exchange through net exports and foreign investments.

The excessive use of snuff among the youth in Benue state is a cause for concern. Snuff was known to be consumed by elderly people but the youths including those in tertiary institutions now consume it. Many see it as a safe substitute for smoked tobacco products while some students see it as a substance for sleep prevention that could be used when reading. It is therefore obvious that the consumers of locally processed snuff tobacco products may have little or no knowledge on the health risk associated with the consumption of these products. Several studies have already analyzed the concentration of the natural radionuclides in cigarette tobacco (Akinyose *et al*., 2018; Shousha *et al.*, 2016, Shousha *et al.*, 2011), but the concentration of these radionuclides (^{40}K, ^{238}U and ^{232}Th) in snuff products processed in Benue state have not been analyzed. This study therefore measured the activity concentration of these natural radionuclides in the snuff products processed as well as consumed in Benue state, and also estimated the radiological parameters associated with the consumption of snuff products.

MATERIALS AND METHODS

Sample Collection

Seven samples of snuff tobacco were collected from six local government areas (LGAs) in Benue state; 1 sample of snuffs made with additives from each of the selected LGA and a sample of an additives-free snuff from Gboko LGA as a control sample. The samples were collected from the major producers of snuff residing within the local government area. These local governments include Apa, Oju, Konshisha, Kwande, Gboko and Guma. 2 local government areas were chosen from each of the 3 geopolitical zones of the state (zone A, B and C); Konshisha and Kwande in zone A, Gboko and Guma in zone B, and Apa and Oju in zone C. The choice of these local governments was based on the fact

that they were actively involved in the cultivation of tobacco as well as production of snuff products within their geopolitical zones. Both the cultivation of tobacco plants as well as processing of the leaves to snuff were thoroughly monitored by the researcher. At the point of collection, samples were carefully labeled and placed in separate polythene bags to avoid cross contamination. The detailed descriptions of various samples are shown in Table 1.

Table 1: A detailed description of samples collection

Sample's ID	Sample's name	Mass of raw sample (g)	Mass of prepared sample(g)	Longitude	Latitude
S1	Apa Snuff	126.3	125.2	7^{0}57'54.89"E	7^{0}44'2.01"N
S2	Oju Snuff	136.9	134.7	8^{0}20'0.52"E	7^{0}0'45.45"N
S3	Konshisha Snuff	139.7	138.1	8^{0}20'38.13"E	7^{0}2'39.66"N
S4	Kwande Snuff	138.0	136.2	9^{0}25'21.93''E	6^{0}56'33.70"N
S5	Gboko Snuff	128.7	126.9	8^{0}57'55.70"E	7^{0}25'53.01"N
S6	Guma Snuff	139.3	137.2	8^{0}42'59.35"E	7^{0}44'38.23"N
A5	Additives-free Snuff	133.6	131.7	8^{0}57'55.70"E	7^{0}25'53.01"N

Sample Preparation
The snuff samples were dried at 105^0C in a temperature controlled oven until there was no detectable change in masses of the samples. Each sample was therefore weighed and sealed for at least 28 days in a clean and uncontaminated air tight random 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.

Specifications and Calibration of the Measuring System
The detector used for the radionuclide's measurements was a lead-shielded 76mm x 76mm NaI(TI) detector crystal (Model No. 802 series, Serial No. coupled to a Canberra series 10 plus Multichannel Analyzer (MCA) (Model No. 1104) through a preamplifier. It is located at the National Institute of Radiation Protection and Research, University of Ibadan campus, Ibadan. The detector has energy resolution of 7.5% at 662 keV peak of ^{137}Cs. Its resolution is therefore considered adequate to distinguish the gamma ray energies of interest in this study. The MCA is a complete system having all functions needed for spectroscopic analysis. The MCA electronic system consists of an internal spectroscopic amplifier (AMP), a 100 MHZ Wilkinson type analog to digital converter (ADC), control logic (CL) with input and output devices and multichannel scaling input, 4 k memory (M), display and analysis (DAL), and screen display (SD). The measuring system has a unique advantage of operating on batteries, which can be trickle-charged. The batteries can run continuously for eight (8) hours, this will prevent interruption in counting in case of power failure. The MCA has facilities to supply a stabilized extra high voltage (EHT) bias to the detector.
The efficiency calibration of the NaI(TI) detector is carried out using a certified standard source in cylindrical geometry, which is placed directly on the detector end-cap. The standard source is a mixed source containing natural radionuclides, from lower energy to higher energy in a cylindrical container.

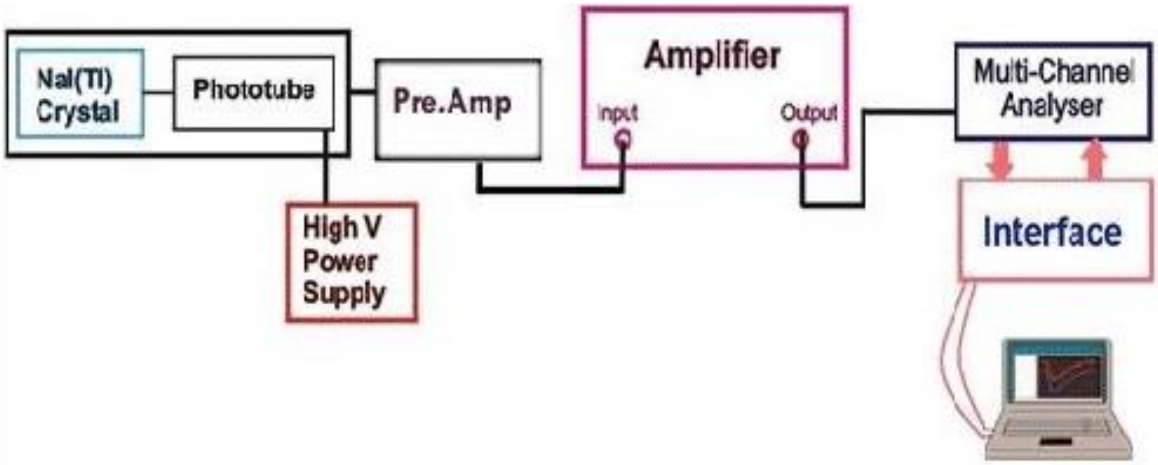

Plate 1: Schematic diagram of the radionuclide measuring system

Radiological Analysis of Samples
Each sealed sample was placed on the NaI(TI) detector crystal and counted for 18,000s. 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 18,000s to determine the background distribution spectrum.
The choice of radionuclides to be detected was predicted on the fact that the NaI(TI) detector used for this study has 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. Thus, the activity concentration of ^{214}Bi (determined from its 1120 keV and 609 keV ɣ-ray peaks) was chosen to provide an estimate of ^{238}U in the samples, while that of the daughter radionuclide ^{228}Ac determined from its 911 keV ɣ-ray peak was chosen as an indicator of ^{232}Th. ^{40}K was determined by measuring the 1460 keV ɣ-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.

Estimation of Radiological Parameters
Activity concentration
The activity concentration of radionuclides measured in snuff products used in Benue state were estimated using equation 1 (Akinyose *et al*., 2018).

$$C = \frac{A}{\varepsilon M s P_{\gamma} T c} \quad (1)$$

Where A is the net area of the peak, **ε** is efficiency of the detector for radionuclide n, M_s is the dried mass of ashed sample for measurement in kg, P_γ is gamma emission probability (or branch ratio), and T_c is the counting time.

Radium Equivalent Activity Index (Ra_{eq}) for snuff

This allows a single index or number to describe the gamma output from different mixtures of ^{40}K, ^{238}U and ^{232}Th in a material. It was calculated using equation 2 (UNSCEAR, 2000).

Ra_{eq} = AU + 1.43ATh + 0.077AK (2)

Where AU, ATh and AK are radionuclide concentrations (Bqkg^{-1}) of ^{238}U, ^{232}Th and ^{40}K respectively.

Annual effective dose (μSvy^{-1}) resulting from daily inhalation of snuff

The annual effective dose resulting from inhalation of snuff was calculated using equation 3 (Akinyose *et al.*, 2018):

E_s = A × M × DCF (3)

Where E_s is the annual effective dose for snuff; A is the activity concentration of radionuclides, 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 2.1×10^{-9}, 2.9×10^{-6} and 4.5×10^{-5} SvBq^{-1} for ^{40}K, ^{238}U and ^{232}Th respectively (ICRP, 2012).

Locally processed snuffs in Benue state are wrapped in nylons for sales. The average mass of one (1) wrap of snuff is 2.3g. Thus, the annual consumption rate of one (1) wrap of snuff daily was estimated as shown below:

M_s= 1 × 365 × 2.3 = 0.8395 kgy^{-1}

Excess Lifetime Cancer Risk (ELCR) resulting from the radionuclide concentration of processed tobacco products

ELCR gives the probability of developing cancer over time at a certain exposure level. This indicator is calculated based on the assumption that the average human lifespan is approximately equal to 70 years. The excess lifetime cancer risk (ELCR) resulting from the radionuclide concentration of snuff was estimated using equation 4 (Akinyose *et al.*, 2018).

ELCR=AEDE × DL × RF (4)

Where AEDE is the annual effective dose equivalent, DL is the average duration of life (estimated to be 70 years), 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 (ICRP, 2012). The Average value of ELCR is given as 0.2 x 10^{-3} (UNSCEAR, 2000; Akinyose *et al.*, 2018).

RESULTS AND DISCUSSION

Results

Table 2: Radionuclide activity concentration and the estimated radiological parameters in snuff tobacco

Sample's code	K-40 (Bqkg^{-1})	U-238 (Bqkg^{-1})	Th-232 (Bqkg^{-1})	Ra_{eq} (Bqkg^{-1})	AED (μSvy^{-1})	ELCR (×10^{-3})
S1	1616.85 ± 79.48	26.90 ± 2.92	6.77 ± 0.39	161.08	324.09	1.13
S2	1959.13 ± 96.36	45.72 ± 5.37	2.81 ± 0.16	200.59	220.92	0.77
S3	1918.34 ± 94.26	27.62 ± 3.19	10.11 ± 0.58	189.79	452.55	1.58
S4	1223.06 ± 60.47	4.39 ± 0.55	17.51 ± 1.03	123.60	674.33	2.36
S5	565.05 ± 28.14	28.86 ± 3.61	4.28 ± 0.25	78.49	232.94	0.82
S6	474.75 ± 23.64	1.93 ± 0.25	8.06 ± 0.47	50.01	310.02	1.09
Mean	**1292.86 ± 63.73**	**22.57 ± 2.65**	**8.26 ± 0.40**	**133.93**	**369.14**	**1.29**
A5	617.73 ± 30.93	26.49 ± 3.05	4.06 ± 0.23	79.86	218.96	0.77

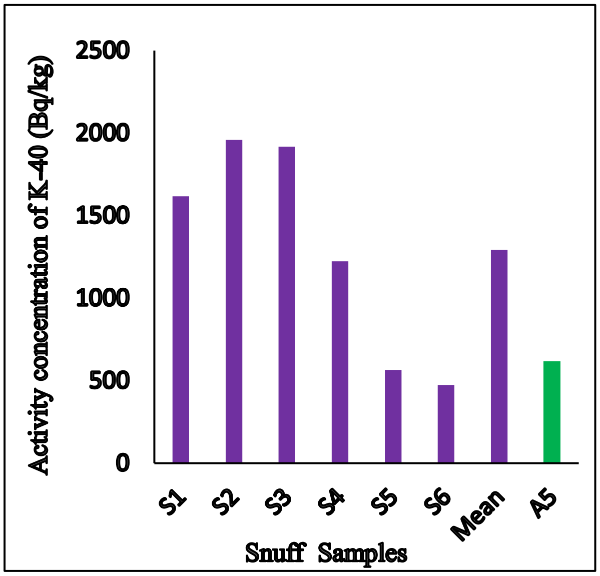

Figure 1: Activity concentration of K-40 in snuff samples

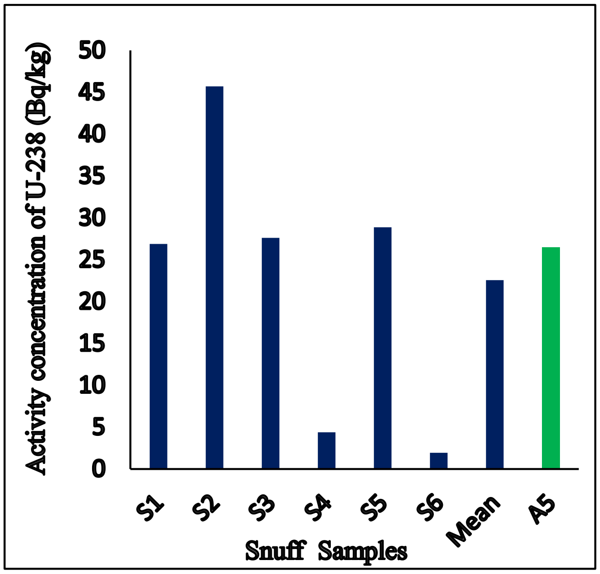

Figure 2: Activity concentration of U-238 in snuff sample

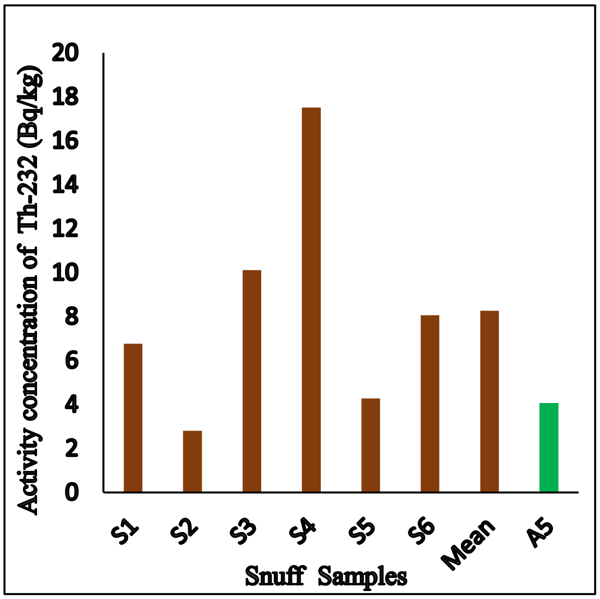

Figure 3: Activity concentration of Th-232 in snuff samples

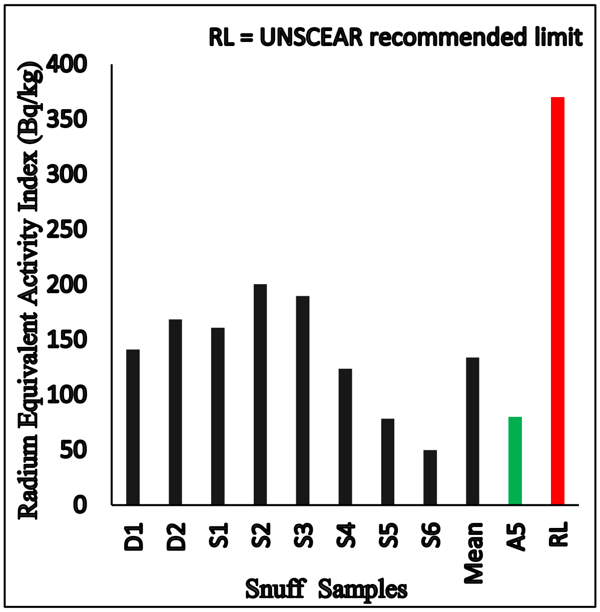

Figure 4: Radium equivalent activity index for snuff samples

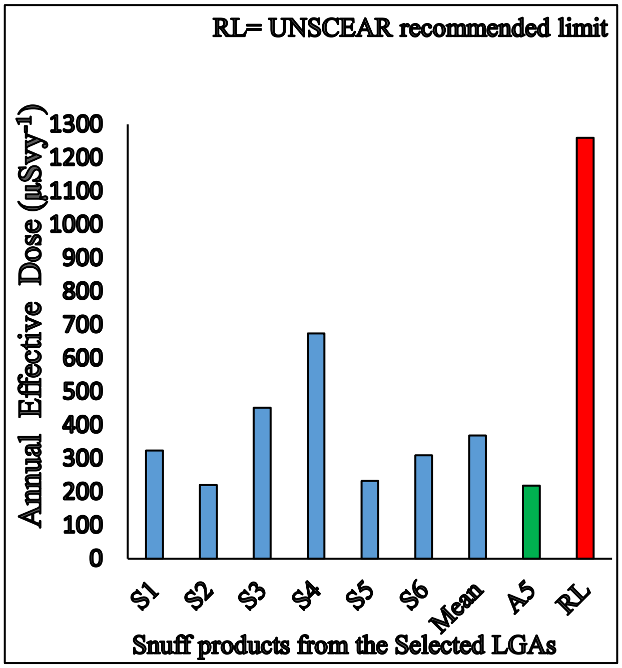

Figure 5: Annual effective doses for inhaling 1 wrap of the snuff products daily

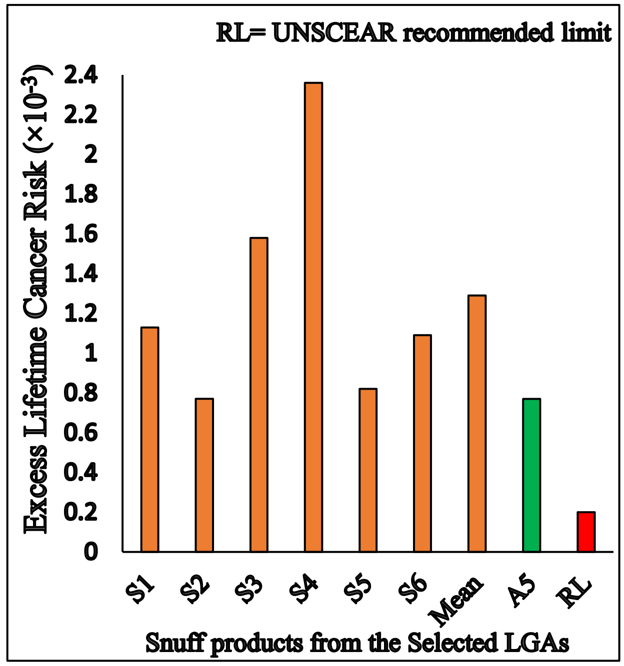

Figure 6: Excess lifetime cancer risk for inhaling 1 wrap of the snuff products daily

Discussion

The activity concentration of natural radionuclides in snuff

As indicated in Table 2 and Figures 1 to 3, the activity concentration of snuff products from the sampled LGAs ranged from 474.75 ± 23.64 Bqkg^{-1} to 1959.13 ± 96.36 Bqkg^{-1} (with a mean of 1292.86 ± 63.73 Bqkg^{-1}), 1.93 ± 0.25 Bqkg^{-1} to 45.72 ± 5.37 Bqkg^{-1} (with a mean of 22.57 ± 2.65 Bqkg^{-1}) and 2.81 ± 0.16 Bqkg^{-1} to 17.51 ± 1.03 Bqkg^{-1} (with a mean of 8.26 ± 0.48 Bqkg^{-1}) for ^{40}K, ^{238}U and ^{232}Th respectively. Among the snuff samples measured, the snuff made in Oju LGA (S2) registered highest activity concentration of ^{40}K while the snuff made in Guma LGA (S6) had the lowest concentration of ^{40}K. For ^{238}U, the snuff from Oju LGA (S2) displayed the highest activity concentration while the snuff from Guma LGA (S6) exhibited the lowest concentration. For ^{232}Th, the snuff produced in Kwande LGA (S4) registered the highest concentration while the snuff produced in Oju LGA (S2) had the lowest concentration. Based on the researcher's investigation for this study, it was found that Benue state tobacco farmers do not use phosphate fertilizers for the cultivation of their tobacco farms, in order to maintain the natural taste of tobacco. Notwithstanding, both ^{40}K, ^{238}U and ^{232}Th are naturally present in all the soil within the study area, and ^{40}K is also high in concentration in the selected LGAs as reported in the works of Kungur *et al.* (2020) and Bashiru *et al.* (2018), the activity concentration of these natural radionuclides in the fresh tobacco leaves used for the processing of snuff products may be due to root uptake by tobacco plants from the soil in the LGAs where the tobacco plants were cultivated. Thus, the differences seen in the activity concentration of the snuff samples could be attributed to the variation in concentration of ^{40}K, ^{238}U and ^{232}Th in the tobacco leaves used for the snuffs production as well as the processing methods employed by different producers of the snuff products across the selected LGAs.

In addition, a control sample (an additives-free snuff) was used to check the influence of additives used for the production of snuff on the activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the snuff products. The result revealed that the introduction of additives may lead to differences (increase or decrease) in activity concentration of snuff. As shown in Table 2 and Figures 1 to 3, the activity concentrations of ^{40}K, ^{238}U and ^{232}Th in the additives-free snuff sample were 617.73 ± 30.93 Bqkg^{-1} 26.49 ± 3.05 Bqkg^{-1} and 4.06 ± 0.23 Bqkg^{-1} respectively, whereas the activity concentrations of a snuff made with additives (S5) that shared tobacco leaves of same source (plants) with the additives-free snuff (A5) during their processing were 565.05 ± 28.14 Bqkg^{-1}, 28.86 ±3.61 Bqkg^{-1} and 4.28 ± 0.25 Bqkg^{-1} for ^{40}K, ^{238}U and ^{232}Th respectively. Since the major additive used for snuff production, potash (kanwa) exhibited varying concentration of ^{40}K, ^{238}U and ^{232}Th with geographical location where they were mined (Garba *et al.*, 2020), the kanwa and other additives used by snuff producers in the selected LGAs for the snuffs production may have led to the increase or decrease in concentration of natural radionuclide in the snuff samples.

Comparison of activity concentration of natural radionuclides in snuff with studies

Not much has been done on the activity concentration ^{40}k, ^{238}U and ^{232}Th in snuff. As found in the study conducted by Akinyose *et al.* (2018b) on the radiological impact of the radionuclides in tobacco products in Oyo state, the snuffs consumed in Oyo state, Nigeria averaged the concentration of these radionuclides as 69.33, 17.41 and 14.55 Bqkg^{-1} for ^{40}K ^{238}U and ^{232}Th respectively. Comparing the two results, ^{40}K seems to be extremely higher in this study. Thus, the higher concentration of ^{40}K in snuff for this study may be attributed to its abundance in the tobacco leaves that were used for the snuff processing.

Radium equivalent index (Ra_{eq}) for the snuff products

As depicted in Table 2 and Figure 4, the values of radium equivalent activity index for snuff products from the selected LGAs ranged from 50.01 Bqkg^{-1} to 200.59 Bqkg^{-1} with a mean of 133.93 Bqkg^{-1} for snuffs made with additives. Among the snuff samples examined from the sampled LGAs, the snuff sample from Oju (S2) had the highest radium equivalent activity, whereas the snuff sample from Guma LGA (S6) recorded the least radium equivalent activity. Also, the snuff samples from Gboko (S5), Kwande (S4), Apa (S1), and Konshisha (S3) obtained their respective radium equivalent activity of 78.49, 123.60, 161.08, and 189.79 Bqkg^{-1}. In addition, the additives-free snuff (A5) recorded the Ra_{eq} of 79.86 Bqkg^{-1} compared to the snuff made with additives (S5) that shared tobacco leaves of same source (plants) which exhibited a Ra_{eq} of 78.49 Bqkg^{-1}. All the estimated values of radium equivalent activity were found to be lower than the UNSCEAR recommended limit of 370 Bqkg^{-1} (UNSCEAR, 2000).

The annual effective doses resulting from daily inhalation of snuff

The results displayed in Table 2 and Figure 5 shows that, the values of annual effective doses resulting from sniffing of one wrap of snuff daily ranged from 220.92 to 674.33 µSvy^{-1} for snuffs containing additives. Amidst the snuff samples assessed, the snuff from Kwande LGA (S4) registered the highest annual effective dose while the snuff from Oju LGA (S2) had the least annual effective dose. Snuff from Gboko (S5), Guma (S6), Apa (S1) and Konshisha (D3) LGAs displayed their respective annual effective doses of 232.94, 310.02, 324.09, and 452.55 µSvy^{-1}.

In the additives free snuff (A5), as indicated in Figure 5, the annual effective dose resulting from sniffing one wrap of snuff daily was 218.96 µSvy^{-1}. This reveals that the health risk associated with a snuff without additives (As) is less compared to the snuff made with additives (S5) that shared tobacco leaves of same source (plants). Note that that the annual effective dose of S5 was 232.94 µSvy^{-1}. All the estimated values of the annual effective doses for consuming one wrap of snuff daily were found to be lower than the world wide average recommended limit for exposure to natural radiation sources, particularly due to inhalation, which is 1260 µSvy^{-1} (UNSCEAR, 2000).

In addition, the result in Table 2 and Figure 5 also shows that, the mean annual effective dose for inhaling 1 wrap of snuff daily was 369.14 µSvy^{-1}. This value was lower than the UNSCEAR recommended limit of 1260 µSvy^{-1}. This infers that, the snuff products consumed in Benue state may be generally considered to be less harmful. However, from the investigations made in this study, it was found that most addicted sniffers consume more than one wrap of snuff daily. This is because tobacco is known to contain nicotine which makes the consumers of its products desiring to consume more (FDA, 2022). Thus, consuming three (4) wraps of snuff daily would result to a mean annual effective dose of 1476.56 µSvy^{-1}. This value is then higher than the recommended limit of 1260 µSvy^{-1} (UNSCEAR, 2000). It therefore means that most addicted snuff consumers are exposed to serious health risks due to increased internal intake of ^{40}K, ^{238}U and ^{232}Th. The calculation for snuff inhalation assumes that all the gamma-emitting radionuclides from snuff reach the lungs (Mwalongo *et al.,* 2023). These values were therefore estimated for the sniffer that successfully inhales the whole mass of 1 wrap and 3 wraps of snuff respectively.

Excess lifetime cancer risk resulting from daily inhalation of smoke from snuff

From the results presented in Table 2 and Figure 6, it was observed that, the estimated values of ELCR for consuming one wrap of snuff daily ranged from 0.77×10^{-3} to 2.36×10^{-3} for snuffs with additives. Amidst the snuff samples analyzed, the snuff from Kwande LGA (S4) obtained the highest value of ELCR, while the snuff from Oju LGA (S2) had the least value of ELCR. Snuffs from Gboko, Guma, Apa and Konshisha LGAs displayed their respective ELCR of 0.82×10^{-3}, 1.09×10^{-3}, 1.13×10^{-3}, and 1.58×10^{-3}. These values were all higher than the UNSCEAR recommended limit of 0.2×10^{-3} (Akinyose *et al.,* 2018).

In additives-free snuff (A5), the value of ELCR was 0.77×10^{-3} whereas S5 (Gboko snuff made with additives) which shared tobacco leaves of same source (plants) with A5, recorded ELCR of 0.82×10^{-3}. One could observe that the ELCR from the snuff with additives is higher when compared to the snuff of same source without additives. However, the estimated value of ELCR for consuming just one (1) wrap of additives-free snuff daily was also higher than the recommended limit of 0.2×10^{-3}. Because the examined radionuclides in snuff for this study were classified as carcinogens by the International Agency for Research on Cancer (IARC, 2012; IARC, 2001), the consumers of all the snuff products analyzed across the sampled local government areas in Benue state are exposed to cancers associated with the consumption of smokeless tobacco (snuff).

CONCLUSION

Based on the findings of this study, the snuff tobacco used in Benue state, Nigeria contain naturally occurring radionuclides from ^{238}U and ^{232}Th series, and non-series ^{40}K. Also, the study revealed that the additives used for the processing of the snuff products, as well as the different processing methods employed in the processing of the products may increase or decrease the concentration of these natural radionuclides in the locally processed snuff tobacco. Furthermore, the annual effective dose and radium equivalent index were lower than the UNSCEAR recommended limit of 1260 μSvy^{-1} and 370 Bqkg^{-1} respectively for inhaling 1 wrap of snuff in one day. In addition, the estimated values of excess lifetime cancer risk (ELCR) were higher than the UNSCEAR recommended limit of 0.2×10^{-3} for inhaling 1 wrap of snuff daily. Thus, the snuff tobacco products processed as well as consumed in Benue state may pose health risks, especially to addicted consumers of the products.

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REFERENCES

Agba H. E., Kungur, S. T., & Akaagerger, N. B. (2012). Radioactivity of local tobacco and some selected brands of cigarettes. International Journal of the Physical Sciences, **7**(2): 205–213.

Akinyose F. C., Tchokossa P., Orosun M. M., Oluyide S. O., Olatunji O. & Martins G. (2018). A Study of Natural Radioactivity and Gamma Radiation Hazard in Tobacco Leaves and Cigarettes in Oyo State, Nigeria. Manila Journal of Science **11**(2018):104-114.

Akinyose F. C., Tchokossa P., Orosun M. M., Oluyide S. O., Umakha M., Ochommadu K. K., Olaniyan T. A & Ajibade O. A. (2018). Radiological Impacts of Natural Radioactivity in Locally Produced Tobacco Products in Ibadan, Oyo State, Nigeria. http://dx.doi.org/10.4314/mejs.v10i1.5.

Bashiru, L., Sombo, T., Tyovenda, A. A., Onukwebe, S. I., & Nwankwo, M. O. (2018). Assessmet of Environmental Radioactivity of Surface Soils in some selected Local Government Area in Benue State. IOSR Journal of applied physics. **10**(3): 84-90.

Belafrites, A., Boumala, D., Tedjani, C. and Groetz, J. (2019). Annual effective dose and excess life time cancer risk assessment from tobacco plants. https://doi.org/10.1016/j.pisc.2019.100394.

Garba N. N., Hannatu J. I., Rose A. O., Suleiman B. & Rabiu N. (2020): Radiological safety assessment of mined Trona commonly consumed in Nigeria, International Journal of Environmental Analytical Chemistry. **102**(19): 8434-8444.

George E. and Fribourg T. (2010). The Old Snuff House of Fribourg and Treyer at the Sign of the Rasp & Crown. Nabu Press, England. ISBN 978-1176904705.

International Agency for Research on Cancer (2012). A review of human carcinogens: personal habits and indoor combustions. IARC monographs on the evaluation of carcinogenic risks to humans, volume 100E. https://monograhs .iarc.fr/wp-conent/uploads/2018/06/mon100E.pdf.

International Agency for Research on Cancer (2012). Io International Agency for Research on Cancer (2012). Ionizing radiation, Part2: some internally deposited radionuclides. IARC monogr Eval Carcinog Risk Hum, **78**: 1-559, PMID: 11421248.

International Agency for Research on Cancer (IARC) (2007). Smokeless Tobacco and Some Tobacco-Specific N-Nitrosamines. http://publications.iarc.fr/122.

International Commission on Radiological Protection (ICRP), (2012). Compendium of Dose Coefficients based on ICRP Publication 60. ICRP Publication 119. Ann. ICRP **41**(Suppl.).

Kungur, S. T., Ige, T. A. & Ikyo, B. A. (2020). Analysis of Natural Radionuclides and Evaluation of Radiation Hazard Indices in Soil Samples from Benue State, Nigeria. ISSN No: -2456-2165.

Mishra S. and Mishra M. B. (2013). Tobacco: its historical, cultural, oral, and periodontal health association. J Int Soc Prev Community Dent. 3(1): 12-18. doi: 10.4103/2231-0762.115708.

Mwalongo D. A., Haneclaus N. H., Carvalho F. P., Lisuma J. B., Kivevele T. T. (2023). Influence of phosphate fertilizers on the radioactivity of agricultural soils and tobacco plants in Kenya, Tanzania, and Uganda. Environmental Science and Pollution Research. **30**: 83004-83023.

Ponte, L., (1986). Radioactivity: The new-found danger in cigarettes. Reader's Digest, 123-127.

Shousha, H. and Ahmad, F. (2012). Natural radioactivity contents in tobacco and radiation dose induced from smoking. Environmental Science Radiation Protection. Corpus ID: 45831556. DOI:10.1093/rpd/ncr375.

Shousha, H.A. and Ahmad, F. (2016). Lifetime cancer risk of gamma radioactivity results from smoking. Radiat. Cancers. **3**(1): 1-9.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (2000). Sources and effects of ionizing radiation. Report presented to general assembly with scientific annexes. V. 1, UN Publication, New York, ISBN: 92-1-142238-5, 653p.

United State Environmental Protection Agency (EPA) (2022). https://www.epa.gov/radtown/radioactivity-tobacco.

United State Environmental Protection Agency (EPA) (2022). https://www.epa.gov/radtown/radioactivity-tobacco.

United State Food and Drug Administration (2022). https://www.fda.gov/tobacco-products/products-ingridients-components/regulation-and-tobacco-nicotine-ntn-products.

World Health Organization (WHO) (2022). WHO reports on global tobacco epidemic. https//www.who.int/news-room/fact-sheets.