Available online at www.worldscientificnews.com

World Scientific News

An International Scientific Journal

WSN 191 (2024) 43-55 EISSN 2392-2192

Assessment of Radionuclide Concentration in Dried and Woven Tobacco Products Consumed in Benue State

M. E. Ikyernum*, T. Sombo, E. V. Tikyaa

Department of Physics, Joseph Sarwuan Tarka University, PMB 2373, Makurdi, Nigeria

*E-mail address: emmysute@gmail.com

ABSTRACTS

Assessment of radionuclide concentration in Dried and Woven Tobacco products (DWT) consumed in Benue state was carried out using a lead-shielded 76mm × 76mm 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 in dried and woven tobacco samples that were collected from Apa, Oju, Konshisha, Kwande, Gboko and Guma 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 DWT samples from the selected LGAs across Benue state were 1110.95 ± 54.80, 17.54 ± 1.91 and 5.06 ± 0.30 Bqkg^{-1} respectively. Meanwhile, the mean value of radium equivalent activity (Ra_{eq}) obtained for the DWT products was 110.32 Bqkg^{-1} and was found to be lower than the UNSCEAR recommended limit of 370 Bqkg^{-1}. The estimated average values of annual effective doses (µSvy^{-1}) were 68.87 and 34.43 for inhaling 100% and 50% of smoke from 1 stick of DWT respectively, in one day. These values were found to be lower than the UNSCEAR recommended limit of 1260 µSvy^{-1}. However, consuming about 40 sticks of DWT (equivalent to 2 packs of cigarettes) daily would result to an annual effective dose of 1337.20 µsvy^{-1} for the primary smoker. This value was therefore found to be higher than the recommended limit of 1260 µSvy^{-1}. In addition, the estimated excess lifetime cancer risk (ELCR) averaged 0.24×10^{-3} and 0.12×10^{-3} for inhaling 100% o and 50% of smoke from 1 stick of DWT respectively, in one day. These values of ELCR were higher than the UNSCEAR recommended limit of 0.2×10^{-3} for inhaling 100% of smoke from 1 stick of DWT daily and the primary smoker consuming at least 2 sticks of DWT daily. Thus, the DWT products processed as well as consumed in Benue state

(Received 08 February 2024; Accepted 28 February 2024; Date of Publication 01 March 2024)

may pose health risks, especially to addicted consumers of the products and it is recommended that public awareness should be made about the harmful effects resulting from DWT tobacco use in order to enlighten the consumers of these products on the alarming health threats associated with dried and woven tobacco.

Keywords**:** Dried and Woven Tobacco, Radionuclides, Activity concentration, Annual effective dose, Excess lifetime cancer risk

1. 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). 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 leaves. The trichomes absorb tiny dust particles from air that contain small amount of radioactive materials (radon and its decay products), which could persist even when the tobacco leaves are dried and processed (Martel, 1974). Tobacco products can be grouped into two forms; these include smoked tobacco products and smokeless tobacco products (Akinyose *et al.,* 2018).

Dried and woven tobacco (DWT) which is referred to as 'Akpena' by Tiv tribe of Benue state is a smoked tobacco product locally processed from naturally cured leaves of tobacco plants. The processing of dried and woven tobacco involves multiple steps which include; curing of tobacco leaves, sprinkling of water on the cured tobacco leaves, softening of the tobacco leaves mid rib by hitting thoroughly with a wooden stick, twisting of few tobacco leaves to form a tobacco string, weaving of DWT using few tobacco strings, and drying the DWT to be ready for consumption. It is then pulverized and wrapped in a paper without filter and smoked like cigarette; by burning and inhalation.

Research has confirmed that 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 use result in varying quantities of radiation to be absorbed into the consumer's blood stream which could cause radiation injuries such as cancer, ulcer, leukemia and other diseases over time (Ponte, 1986). Studies have stated that smoked tobacco products cause cancers of the bladder, oral cavity, pharynx (voice box), esophagus, cervix, kidney, lungs, pancreas and stomach, and causes acute myeloid leukemia. Smoked tobacco products also cause heart diseases and stroke (Khater, 2004; Papastefanou, 2009; Landsberger *et al.,* 2015; Akinyose *et al.,* 2018; Belafrites *et al.,* 2019).

The rate of consumption of dried and woven tobacco by the people of Benue state is alarming. Considering the fact that DWT is cheaper in price as compared to cigarettes, the population of DWT smokers is increasing daily. Another factor that triggers the use of akpena (DWT) among the people of Benue state is the assumption made by some consumers of locally processed tobacco products who are aware that phosphate fertilizer is one of the main sources of radionuclides in tobacco. They assume that since Benue farmers do not use phosphate fertilizers for the growing of their tobacco farms; as a measure to maintain the natural taste of tobacco, the DWT products originating from the tobacco plants grown in Benue state may not be radiologically harmful.

Plate 1. Dried and Woven Tobacco Processed in Benue State

This assumption was made known to the researcher while interviewing DWT smokers in Benue state in order to acquire some facts for this study. It is therefore obvious that the consumers of akpena may have little or no knowledge on the health risk associated with the consumption of these products. Several studies have already analyzed the activity concentration of natural radionuclides in cigarette tobacco, but the concentration of these radionuclides (^{40}K, ^{238}U and ^{232}Th) in DWT products in Benue state have not been analyzed. This study therefore measured the activity concentration of these natural radionuclides in the dried and woven tobacco products processed as well as consumed in Benue state, and also estimated the radiological parameters associated with the consumption of DWT products.

2. MATERIALS AND METHODS

2. 1. Sample Collection

Six samples of dried and woven tobacco products were collected from six local government areas (LGAs) in Benue state; 1 sample from each of the selected LGA. The samples were collected from the major producers of DWT 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 DWT products within their geopolitical zones. Both the cultivation of tobacco plants as well as processing of the leaves to finished products 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
D1	Apa DWT	398.5	131.8	7°57'54.89"E	7°44'2.01"N
D2	Oju DWT	427.1	126.1	8°20'0.52"E	7°0'45.45"N
D3	Konshisha DWT	356.7	132.4	8°20'38.13"E	7°2'39.66"N
D4	Kwande DWT	382.8	133.8	9°25'21.93''E	$6^0$56'33.70"N
D5	Gboko DWT	410.2	136.7	8°57'55.70"E	7°25'53.01"N
D6	Guma DWT	473.6	128.8	8°42'59.35"E	7°44'38.23"N

2. 2. Sample Preparation

The dried and woven tobacco samples were dried at 105 °C in a temperature controlled oven until there was no detectable change in masses of the samples. The samples were then grinded thoroughly to obtain their powder form. 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.

2. 3. Specifications and Calibration of the Measuring System

The detector used for the radionuclide's measurements was a lead-shielded 76mm × 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 rays 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.

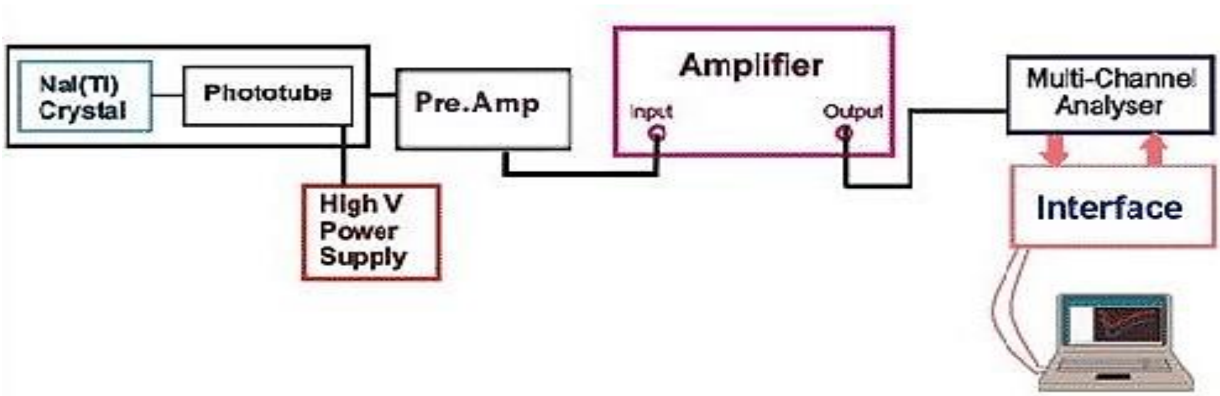

Plate 2. Schematic diagram of NaI(TI) Detector

2. 4. 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 γ -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 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.

2. 5. Estimation of Radiological Parameters

2. 5. 1. Activity concentration

The activity concentration of radionuclides measured in locally processed tobacco products commonly 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, M_s is dried mass of ashed sample for measurement in kg, P_{γ} is gamma emission probability (or branch ratio), and T_c is counting time.

2. 5. 2. Radium Equivalent activity Index (Ra_{eq}) for processed tobacco products

Radium Equivalent activity 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).

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

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

2. 5. 3. Annual Effective Dose Resulting from Daily Inhalation of DWT Smoke

About 74.7% of the radioisotope in cigarette tobacco is contained in cigarette smoke, which is partially inhaled and deposited in body tissues, 20.7% is contained in cigarette ash and 4.6% in cigarette filter. The annual effective dose due to inhalation of cigarettes smoke is therefore estimated using equation 3 (Khater, 2004; Landsberger *et al.*, 2015; Akinyose *et al.*, 2018).

$$E = 0.75 \times A \times M \times DCF \quad (3)$$

Since dried and woven tobacco is wrapped in a paper without filter and smoked like cigarette, about 79% of radionuclide will be contained in DWT smoke, which is partially inhaled and deposited in body tissues, and 21% will be retained in the ash. Thus, the annual effective dose from DWT smoke was calculated using equation 4

$$E_{DWT} = 0.79 \times A \times M_{DWT} \times DCF \quad (4)$$

At least 50% of the cigarette smoke was said to be inhaled by primary smoker (Khater, 2004; Akinyose *et al.*, 2018). Hence, the annual effective dose inhaled from DWT smoke by primary smokers was calculated using equation 5.

$$E_{DWTp} = 0.5 \times E_{DWT} \quad (5)$$

where E_{DWT} is the annual effective dose for dried and woven tobacco smoke, E_{DWTp} is the annual effective dose due to inhalation of dried and woven tobacco smoke by primary smoker, and M_{DWT} is the consumption rate in mass for DWT per year.

The average mass of DWT per a rolled stick of DWT is 0.85g. Therefore, the annual consumption rate of one stick of DWT daily was estimated as shown below:

$$M_{DWT} = 1 \times 365 \times 0.85 = 0.31025 \text{ kgy}^{-1}.$$

2. 5. 4. 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 processed tobacco products was estimated using equation 6 (Avwiri *et al*., 2014; Akinyose *et al.*, 2018).

$$ELCR = AEDE \times DL \times RF \quad (6)$$

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 0.2×10^{-3} (UNSCEAR, 2000; Akinyose *et al.*, 2018).

3. RESULTS

Table 2. Radionuclide activity concentration and the estimated radiological parameters in dried and woven tobacco

S. code	K-40 ($Bqkg^{-1}$)	U-238 ($Bqkg^{-1}$)	Th-232 ($Bqkg^{-1}$)	Ra_{eq} ($Bqkg^{-1}$)	E_{DWT} (μSvy^{-1})	E_{DWTp} (μSvy^{-1})	ELCR ($\times 10^{-3}$)	$ELCR_p$ ($\times 10^{-3}$)
D1	1453.74 ± 71.43	24.34 ± 2.61	3.51 ± 0.21	141.30	56.76	28.38	0.20	0.10
D2	1651.63 ± 81.44	41.23 ± 4.48	BDL	168.41	30.16	15.08	0.11	0.06
D3	1820.29 ± 89.53	21.62 ± 2.34	7.11 ± 0.42	171.95	94.72	47.36	0.33	0.17
D4	1113.24 ± 55.16	1.63 ± 0.21	10.62 ± 0.63	102.54	118.86	59.43	0.42	0.21
D5	317.28 ± 15.83	15.64 ± 1.69	3.03 ± 0.17	44.40	44.70	22.35	0.16	0.08
D6	309.49 ± 15.39	0.77 ± 0.10	6.10 ± 0.36	33.32	67.99	34.00	0.24	0.12
Mean	**1110.95 ± 54.80**	**17.54 ± 1.91**	**5.06 ± 0.30**	**110.32**	**68.87**	**34.43**	**0.24**	**0.12**

Table 3. Comparison of activity concentration of natural radionuclides in dried and woven tobacco (DWT) with studies conducted on cigarettes.

Location	Country	Detector	Concentration ($Bqkg^{-1}$) K-40	U-238	Th-232	Product	Reference
Benue	Nigeria	NaI(TI)	1110.95	17.54	5.06	DWT	This Study
Ibadan	Nigeria	NaI(TI)	48.37	17.52	12.39	Cigarette	Akinyose et al. (2018)
Giza	Egypt	HPGe	1360.4	5.4	4.5	Cigarette	Shousha & Amad (2016)
Baghdad	Iraq	HPGe	1050.64	14.86	10.84	Cigarette	Ridha & Hasan (2016)
Giza	Egypt	HPGe	1157.66	3.56	1.80	Cigarette	Shousha & Amad (2011)

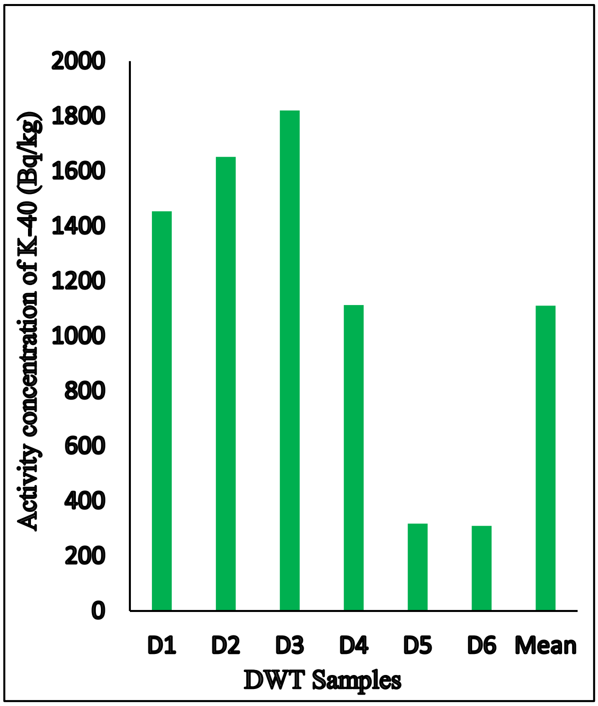

Figure 1. Activity concentration of K-40 in dried and woven tobacco products

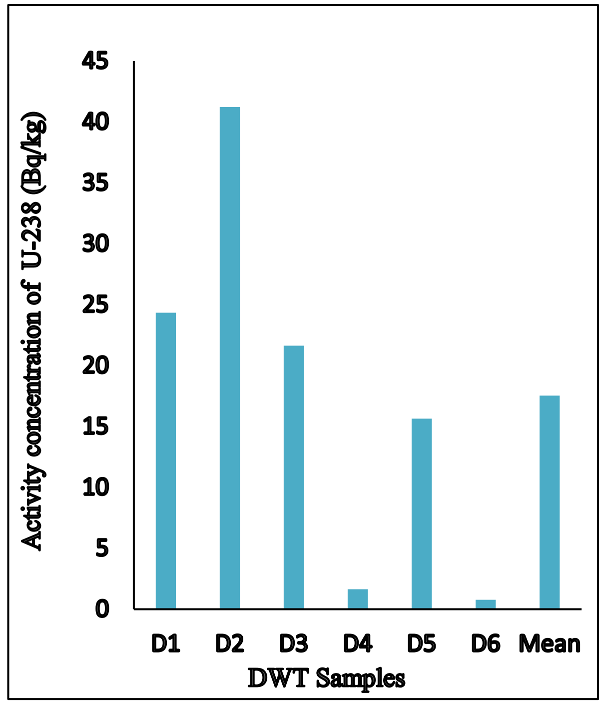

Figure 2. Activity concentration of U-238 in dried and woven tobacco products

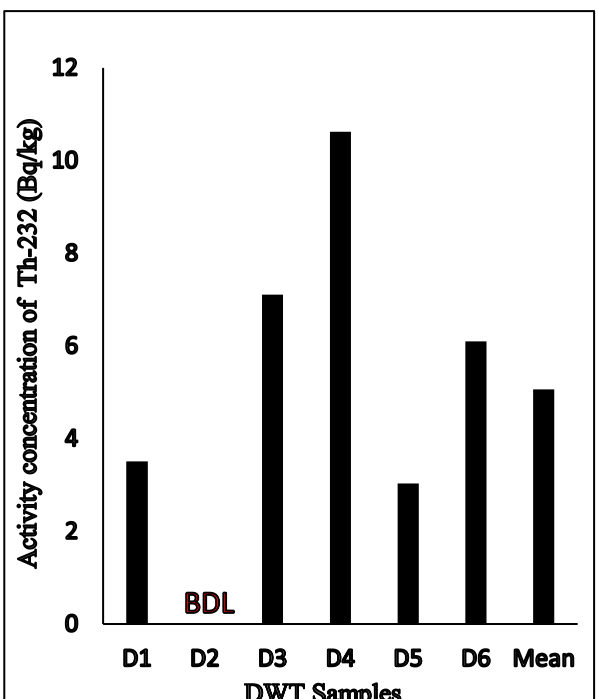

Figure 3. Activity concentration of Th-232 in dried and woven tobacco products

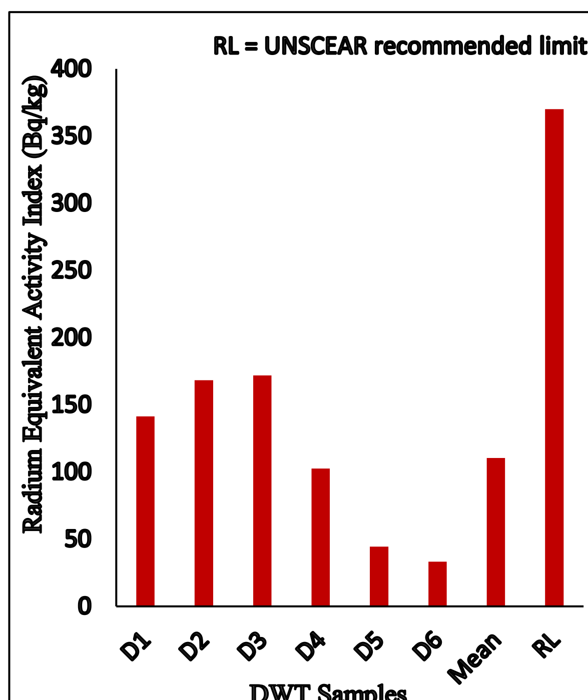

Figure 4. Radium equivalent activity index for the dried and woven tobacco products

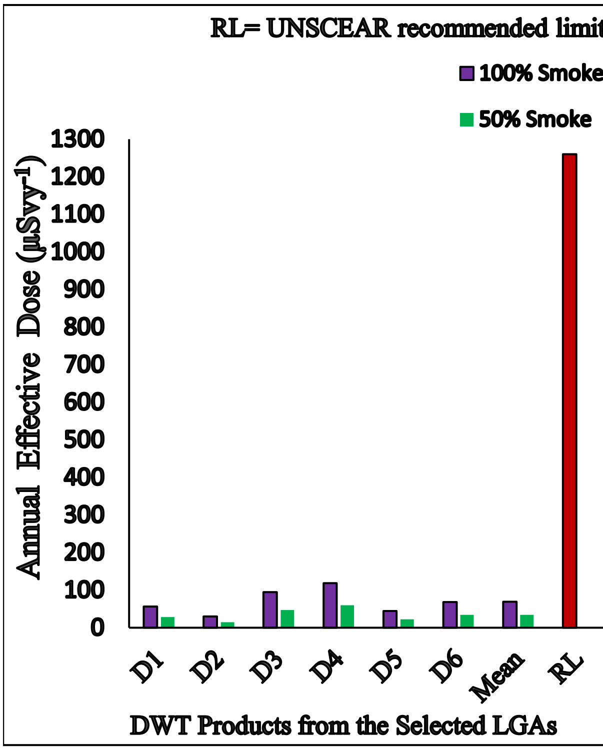

Figure 5. Annual effective doses for inhaling 100% and 50% smoke from 1 stick of DWT daily

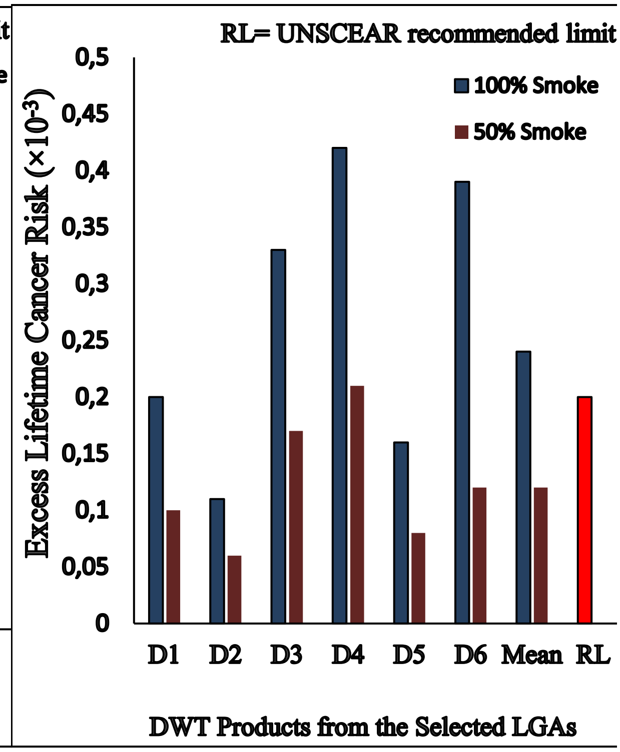

Figure 6. **Excess lifetime cancer risk for inhaling 100% and 50% smoke from 1 stick of DWT daily**

4. DISCUSSION

4. 1. The Activity Concentration of Natural Radionuclides in Dried and Woven Tobacco (DWT)

As indicated in Table 2 and Figure 1 to 3, the activity concentration of DWT from the sampled LGAs ranged from 309.49 ± 15.39 $Bqkg^{-1}$ to 1820.29 ± 89.53 $Bqkg^{-1}$ (with a mean of 1110.95 ± 54.80 $Bqkg^{-1}$), 0.77 ± 0.10 $Bqkg^{-1}$ to 41.23 ± 4.48 $Bqkg^{-1}$ (with a mean of 17.54 ± 1.91 $Bqkg^{-1}$) and 3.03 ± 0.17 $Bqkg^{-1}$ to 10.62 ± 0.63 $Bqkg^{-1}$ (with a mean of 5.06 ± 0.30 $Bqkg^{-1}$) for ^{40}K, ^{238}U and ^{232}Th respectively. The highest activity concentration of ^{40}K was measured in DWT processed in Konshisha LGA (D3) whereas the lowest activity concentration of ^{40}K was obtained in DWT processed in Oju LGA (D6). For ^{238}U, the DWT processed in Oju LGA (F2) exhibited the highest activity concentration, while the DWT processed in Guma displayed the lowest activity concentration. For ^{232}Th, the DWT processed in Kwande LGA (D4) recorded the highest activity concentration whereas, the DWT from Gboko LGA (D5) had the lowest activity concentration.

The processing of Dried and woven tobacco involves multiple steps. These processing methods were carried out by different producers of DWT across the sampled LGAs, thus the differences in activity concentration of DWT could be attributed to the processing methods employed by the DWT producers as well as the variation in radionuclides concentration of ^{40}K, ^{238}U and ^{232}Th in the fresh tobacco leaves used for processing the various dried and woven tobacco products. Also, 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 the dried and woven tobacco products may be due to root uptake by tobacco plants from the soil in the LGAs where the tobacco plants were cultivated.

4. 2. Comparison of activity concentration of natural radionuclides in dried and woven tobacco with studies conducted on cigarettes

Since dried and woven tobacco is wrapped in a paper without filter and smoked like cigarette, the activity concentrations of these natural radionuclides (^{40}K, ^{238}U and ^{232}Th) in DWT need to be compared with that of studies conducted on cigarettes. As presented in Table 3, the overall mean activity concentrations of these radionuclides in DWT seemed to be higher except for ^{232}Th where the overall mean concentration of studies conducted on cigarettes was higher. Also, some activity concentrations of ^{40}K and ^{232}Th in studies conducted on cigarettes were seen to higher than in the DWT for this study. Owing to this, it can't be concluded that DWT has higher concentration of these natural radionuclides (^{40}K ^{238}U and ^{232}Th) than cigarettes. It is also important to note that the activity concentration of these products (DWT and Cigarettes) depends on the source of the raw material (tobacco plants) and the processing methods and techniques involved in processing the products. For instance, as indicated in Table 3, ^{40}K records activity concentration of 1360.4 and 48.37 in studies conducted by Shousha *et al.* (2016) and Akinyose *et al.* 2018 respectively. Trying to reduce the concentration of ^{40}K in cigarette of Shousha's study (1360.4) to equal the concentration of ^{40}K in cigarette of Akinyose's study (48.37) would really become a tough task for cigarettes producing companies. Thus, it can be concluded that DWT is not a safe substitute to cigarettes as it also contains natural radionuclides like cigarettes. Consequently, DWT may be more harmful than cigarettes due to the absence of filter while smoking it.

4. 3. Radium equivalent index (Ra_{eq}) for dried and woven tobacco

From the results in Figure 4, the values of radium equivalent index for DWT samples from the selected LGAs ranged from 33.32 $BqKg^{-1}$ to 171.95 $BqKg^{-1}$ with a mean of 110.32 $BqKg^{-1}$. The DWT sample from Konshisha LGA (D3) recorded the highest radium equivalent activity, while the DWT from Guma LGA (D6) registered the least radium equivalent activity. The DWT from the other LGAs; Gboko (D5), Kwande (D4), Apa (D1), and Oju (D2) obtained the radium equivalent activity of 44.40, 102.54, 141.30, and 168.41 $BqKg^{-1}$ respectively. All the estimated values of Ra_{eq} were found to be lower than the United Nation Scientific Committee on the Effects of Atomic Radiation recommended limit of 370 $BqKg^{-1}$ (UNSCEAR, 2000).

4. 4. The annual effective doses resulting from daily inhalation of smoke from DWT

DWT exhibited different effective doses across the sampled LGAs. In Figure 5, the annual effective doses of 100% of smoke from one stick of DWT daily ranged from 30.16 μsvy^{-1} to 118.86 μsvy^{-1} with a mean of 68.87 μsvy^{-1}. In addition, the annual effective doses for inhaling

50 % of DWT smoke daily by the primary smoker ranged from 15.08 μsvy^{-1} to 59.43 μsvy^{-1} with a mean of 34.43 μsvy^{-1}. All the estimated values of annual effective doses of 100% and 50% of smoke from one stick of DWT daily were lower than the United Nation Scientific Committee on the Effect of Atomic Radiation recommended limit of 1260 μsvy^{-1} (UNSCEAR, 2000) and hence do not pose serious health risk to the consumers of DWT products. However, nicotine which is the cause of addiction to tobacco use would not allow a smoker to just consume one stick of DWT per day.

In fact, World Health Organization (WHO) states that when tobacco users become aware of the dangers of tobacco, most want to quit. However, nicotine contained on tobacco products is highly addictive and without cessation support, only 4% of users who attempt to quit tobacco use will succeed (WHO, 2023). Thus, the estimated mean annual effective doses for inhaling 100% and 50% smoke from 40 sticks of DWT (two packs of cigarettes equivalent) daily would be 2754.80 μsvy^{-1} and 1337.20 μsvy^{-1} respectively. Also, the primary smoker consuming about 37 sticks of DWT daily would receive a mean annual effective dose of 1273.91 μsvy^{-1}. These values were higher than the UNSCEAR recommended limit of 1260 μsvy^{-1}. Since tobacco kills up to half its users directly and many others through exposure to second-hand smoke (WHO, 2023), consumers of about 37 sticks of DWT per day are hence exposed to serious health risks that could result to their deaths. Also, daily exposure to DWT smoke by the passive smokers over time may also result to some radiation injuries.

4. 5. Excess lifetime cancer risk resulting from daily inhalation of smoke from DWT

As depicted in Figure 6, the estimated values of ELCR for DWT samples from the selected LGAs ranged from 0.11×10^{-3} to 0.42×10^{-3} with a mean of 0.24×10^{-3} for 100% smoke from one (1) stick of DWT daily. Except for Gboko LGA, all the estimated values of ELCR for 100% of smoke from one stick of DWT daily were higher than the United Nation Scientific Committee on the Effects of Atomic Radiation recommended limit of 0.2×10^{-3} (Akinyose *et al.*, 2018). Also, as illustrated in Figure 6, the ELCR varies between 0.06×10^{-3} and 0.21×10^{-3} with a mean of 0.12×10^{-3} for the primary smoker inhaling 50% of smoke from one stick of DWT per day. The ELCR for the primary smoker was seen to be lower than the UNSCEAR recommended limit. This is just for the consumer of only one (1) stick of DWT per day.

Estimating ELCR for an addicted primary smoker consuming at least 2 sticks of DWT daily would be higher (0.24×10^{-3}) than the UNSCEAR recommended limit of 0.2×10^{-3}. Since smoked tobacco products cause cancers of the bladder, oral cavity, pharynx (voice box), esophagus, cervix, kidney, lungs, pancreas and stomach (Khater, 2004; Papastefanou, 2009; Landsberger *et al.*, 2015; Akinyose *et al.*, 2018; Belafrites *et al.*, 2019), consuming 2 sticks of DWT daily hence poses cancer risks to both primary and passive smokers.

5. CONCLUSION

Based on the findings of this study, the dried and woven tobacco products in Benue state, Nigeria contain naturally occurring radionuclides from ^{238}U and ^{232}Th series, as well as non-series ^{40}K, and the radium equivalent activity for the DWT products are lower than the UNSCEAR recommended limit of 370 Bqkg^{-1}. Also, the estimated annual effective doses for inhaling 100% and 50% of smoke from 1 stick of DWT in one day were lower than the UNSCEAR recommended limit of 1260 μSvy^{-1}. Furthermore, the estimated mean values of excess lifetime cancer risk (ELCR) were higher than the UNSCEAR recommended limit of 0.2×10^{-3} for inhaling 100% of smoke from 1 stick of DWT daily, and for the primary smoker inhaling 50% of smoke from 2 stick of DWT daily. Thus, the DWT products processed as well as consumed in Benue state may pose health risks, especially to addicted consumers of the products. It is therefore recommended that public awareness should made about the harmful effects resulting from dried and woven tobacco use in order to enlighten the consumers of these products on the alarming health threats associated with the consumption of the DWT tobacco products.

References

[1] 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

[2] 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

[3] 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. *Momona Ethiopian Journal of Science* 10(1): 5 9-75. Doi:10.4172/2161-0398.1000262

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

[5] Boumala, D., A. Belafrites, A. Tedjani, Ch. Mavon, J.-E. Groetz. Annual effective dose and excess life time cancer risk assessment from tobacco plants. *Perspectives in Science,* Volume 12, 2019, 100394, https://doi.org/10.1016/j.pisc.2019.100394

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

[7] Khater, A. E., (2004). Polonium-210 budget in cigarettes. *J. Environ. Radioactivity,* 71: 33-41

[8] 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. *International Journal of Innovative Science and Research Technology* 5(5), 1765-1769

[9] Landsberger, S., Lara, R. & Landsberger, S. G. (2015). Non-destructive determination of^{238}U, ^{232}Th and ^{40}K in tobacco and their Implication on radiation dose levels to the human body. *Radiation Dosimetry,* 167(4): 1-3

[10] Martell, E. A., (1974). Radioactivity of tobacco trichomes and insoluble cigarette smoke particles. *Nature,* 249: 215-217

[11] 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

[12] Papastefanou C. Radioactivity of Tobacco Leaves and Radiation Dose Induced from Smoking. *International Journal of Environmental Research and Public Health*. 2009; 6(2): 558-567. https://doi.org/10.3390/ijerph6020558

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

[14] Ridha, A. A. and Hasan, H. A. (2016). Cancer Risk Due to the Natural Radioactivity in Cigarette Tobacco. *Detection*, 4, 54-65. http://dx.doi.org/10.4236/detection.2016.43008

[15] 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.

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

[17] 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.

[18] World Health Organization (2023). Global Accelerated Action for Adolescents (AA-HA!). Guidance to support country implementation. Second Edition. ISBN: 978-92-4-008176-5