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Estimation of Natural Radioactivity in some Popular Drinks in Nigeria and its Radiological Effect

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RESEARCH ARTICLE

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Abstract: The activity concentration on natural radionuclide in some samples of commonly consumed drinks have been determined using a gamma spectrometer, NaI detector. The mean activity concentration of ^{40}K, ^{232}Th, and ^{238}U in the drink samples were estimated to be 23.76 ± 1.57, 1.55 ± 0.11, and 0.78 ± 0.16 Bq/L respectively. The mean effective dose equivalent of these natural radionuclides in food drinks are 5.77, 15.35, and 11.13 µSv/y respectively for ^{40}K, ^{232}Th, and ^{238}U, while the mean total effective dose equivalent from all the natural radionuclides is 32.25 µSv/y. This value is less than the 0.1 mSv/y and 1 mSv/y recommendation of WHO and NCRP respectively for maximum permissible effective dose for public exposure. The excess lifetime cancer risk was estimated to be 1.13 x 10^{-4}, which is lower than the world average. This is an indication that there is no significant cancer risk to humans as a result of the radionuclides consumption from these food drinks.

Keywords: *Activity Concentration; Natural Radionuclides; Effective Dose; Cancer Risk; Food Drinks.*

INTRODUCTION

Naturally occurring radioactive materials are extant in the earth, they form part of soils, rocks, water, food, and it can also be detected in the human body. A drink is a liquid intended for human consumption. In addition to their basic function of quenching thirst, water and drinks play important roles in human culture and metabolism. Common types of drinks include water, milk, coffee, tea, hot chocolate, wine, juice, and soft drinks.

It is a well-known fact that. Uranium-238 and Thorium-232 are the parents of two complex series of radioactive elements. The Uranium-238, Uranium-235, and Thorium-232, as well as Potassium-40, are of specific importance. They decay to daughter radionuclides like Radium-226and Radium-228 from Uranium-238 and Thorium-232 decay series respectively. These radionuclides are found in oil and gas products, produced water, all sludge and scale deposits in the subsurface and/or surface production facilities.

Naturally occurring radionuclides are divided into three categories, they are primordial, cosmogenic, and human-produced (UNSCEAR, 2000; Tzortzis*et al*., 2003). Primordial radionuclides and cosmogenic radionuclides, such as nuclides from the ^{232}Th and ^{238}U series (and their daughter atoms) and ^{40}K, occur in all ground formations at trace quantities (UNSCEAR, 2000). The distribution of these naturally occurring radionuclides is dependent on the distribution of rocks from which they originate and the process which concentrates them (Mohanty*et al.*,2004). Natural radionuclides are widely spread out in the environment; therefore, they are the major sources of radiation exposure to the general populace (RIN, 2004).

Concentrations of naturally occurring radionuclides in foods and drinks vary widely because of the different background levels, climate, and prevalent agricultural methods and conditions. The knowledge of the environmental radionuclide's concentration and distribution in consumed products are vital due to the health hazard they pose to the human population.

Radioactive materials spontaneously decay to produce ionizing radiation, which could have sufficient energy to remove electrons from atoms, thereby creating two charged ions, it could also break some chemical bonds. Therefore, living tissues in the human body can be affected by this ionizing radiation in a significant manner.

Methodology

Eight different drink samples were collected which include; 7up, Chapman, five-alive, coca-cola, malta Guinness, pure water, pepsi, and hollandiayog hurt. These samples were processed and prepared according to IAEA standard (IAEA,1989), and the samples were taken down to the

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National Institute for Radiation Protection and Research (NIRPR), University of Ibadan, Nigeria. The samples were stored in a refrigerator overnight to prevent fermentation. A Shielded NaI gamma ray spectrometer was used for the measurement of activity concentration of radionuclides. The counting was done for an accumulative period of30,000 seconds per sample to increase the precision of radiometric measurements.

Gamma spectroscopy is ideal for this kind of analysis because it has the ability to measure the radiation emitters directly in their pristine form in the original sample without first going through the rigorous task of chemical separation hence it allows for qualitative and quantitative determination of the various radionuclides in the samples.

Determination of Radioisotopes by Gamma-Ray Spectrometry

The gamma-ray spectrometry analysis was carried out at the National Institute of Radiation Protection and Research (NIRPR), the University of Ibadan using a Canberra NaI detector (model UNISPEC, serial no 22060316). Energy Calibration Sources were Am-241, Cs-137, and Co-60. The complete electronic instrumentation was connected to a PC-based multi-channel analyzer for gamma-spectrum evaluation.

The energy and efficiency calibration of the NaI detector was carried out with IAEA Mixed Sediment Standard consisting of K-40, U-238, and Th-232 using the 1.33 MeV gamma line of Co-60 resulting to energy resolution of 2.3 keV (Full Width at Half Maximum, FWHM) with a relative yield of 1.73%. Each sample was put into an acid-washed marinelli beaker (cylindrical plastic container) which was firmly sealed for a minimum of 28 days in order for secular equilibrium to be attained. The samples were then counted for 30,000 s each after they had attained secular equilibrium. The gamma spectrum peak area analysis and quantification was done with Genie 2000 software. The activity concentrations of the radionuclides (^{40}K, ^{238}U, and ^{232}Th) were determined using the equation 1:

$$A_c = \frac{C_n}{P_\gamma V E} \qquad 1$$

A_C = activity concentration of the radionuclide in the sample in Bq/L

C_n = net count under the corresponding peak

Pγ = absolute transition probability of the specific gamma ray

V = volume of the sample (L);

ε = detector efficiency at the specific gamma ray energy).

Annual Effective Dose Equivalent

Calculation of the annual effective dose due to the ingestion of food items was performed based on the metabolic model developed by the International Commission on Radiological Protection. Effective doses resulting from the intake of ^{238}U, ^{232}Th an ^{40}K may be determined directly from external measurements from concentrations in the body or estimated from concentrations in intake minerals such as air, food, and water (Ahmed, 2004). The effective dose from a radionuclide (r) in a drink (d) can be determined by

$$D_{rd} = A_{rd}C_rR_d \qquad 2$$

Where

D_{rd} = effective dose due to ingestion of the radionuclides. (mSv/y)

A_{rd} = activity concentration of the radionuclides in the ingested drinks. (Bq/Kg)

C_r = effective dose conversion factor by ingestion of the radionuclides. (Sv/Bq)

R_d = consumption rate of the drinks. (Kg/y)

The excess lifetime cancer risks which deal with the probability of developing cancer over a lifetime at a given exposure level was also calculated. It is presented as a value representing the number of cancers expected in a given number of people on exposure to a carcinogen at a given dose. It is worth noting that an increase in the ELCR causes a proportionate increase in the rate at which an individual can get cancer of the breast, prostate, or even blood. Excess lifetime cancer risk (ELCR) was estimated by equation 2 (Taskin*et al*. 2009)

$$ELCR = AEDE \times DL \times RF \times 10^{-3} \qquad 3$$

where AEDE is the annual effective 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 the public (Taskin*et al.* 2009).

Results and Discussion

The results obtained from the analysis of the samples for natural radioactivity using gamma ray spectrometry are presented in Table 1.

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Table 1: Activity concentration of the various radionuclides present in each sample.

S/N	Sample Code	K-40 (Bq/L)	Th-232 (Bq/L)	U-238 (Bq/L)
1	7up	23.17±1.45	4.76±0.34	BDL
2	Chapman	19.25±1.24	4.01±0.29	BDL
3	Coke	39.76±2.79	0.48±0.04	1.44±0.31
4	Fivealive	18.18±1.43	BDL	1.28±0.27
5	HollandiaYoughurt	52.54±3.01	2.62±0.19	BDL
6	Malta Guiness	8.54±0.72	0.56±0.05	3.55±0.72
7	Pepsi	19.31±1.19	BDL	BDL
8	Pure Water	9.28±0.76	BDL	BDL

Table 2: The dose conversion factor(Sv/Bq) for ^{238}U, ^{232}Th, and ^{40}K.

Radionuclide	1 - 2 y	2 - 7 y	7 – 12 y	12 - 17 y	>17 y
U-238	9.6E-7	6.2E-7	8.0E-7	1.5E-6	2.8E-7
Th-232	4.5E-7	3.5E-7	2.9E-7	2.5E-7	2.3E-7
K-40	4.2E-8	2.1E-8	1.3E-8	7.6E-7	6.2E-9

The major natural radionuclide detected in all the samples analyzed is ^{40}K, ^{232}Th and ^{238}U were detected in some of the samples as presented in Table 1. The highest value of activity concentration for ^{40}K 52.54±3.01Bq/L is obtained from Hollandia yoghurt, while the lowest value 8.54±0.72 Bq/L is obtained from Malta Guinness. This may be due to the fact that hollandiayoghourt is more of a fruit base which are rich in potassium. This potassium are the basic requirement for plant growth which could be transferred to the fruit from the potassium-rich soil. For ^{232}Th the highest value 4.76±0.34Bq/L is obtained from 7up and the lowest value 0.48±0.04Bq/L is obtained from Coca-Cola. The concentration of potassium was found to be very high when compared to uranium and thorium as illustrated in figure 1. Potassium is a micronutrient and it may be expected that soil characteristics favor the mobilization of potassium and its subsequent migration into the plant. However, ^{40}K is an essential biological element and its concentration in human tissue is under close metabolic control.

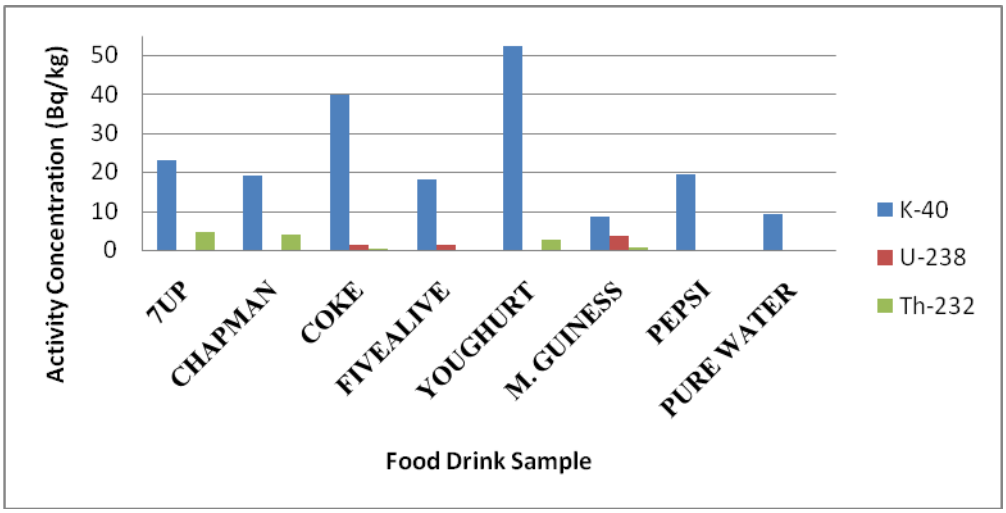

Figure 1 Comparison of K-40, U-238, and Th-232 concentration levels.

The dose conversion factor was taken from the Compendium of Dose Coefficients based on the International Commission on Radiological Protection (ICRP, 2012) and presented in Table 2. The consumption rates were obtained from Nigeria's Food Balance Sheet (FOS, 2013). The annual effective doses were calculated using equation 2 to estimate the radiological implications of the consumption of the investigated drinks. The total annual effective dose to members of the public was calculated using equation 2 and the result is presented in Table 3 and illustrated in figure 2.

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Table 3: Effective dose and total effective dose of the radionuclides

Samples	Effective Dose (µSv/y)			Total Effective Dose (µSv/y)
	K-40	Th-232	U-238	
7up	7.06	53.8	0.00	60.86
Chapman	6.80	52.5	0.00	59.30
Coca-Cola	12	5.42	19.8	37.22
Five-alive	6.4	0.00	20.4	26.80
HollandiaYoghurt	2.58	4.77	0.00	7.35
MaltaGuinness	2.6	6.33	48.8	57.73
Pepsi	5.88	0.00	0.00	5.88
Pure Water	2.83	0.00	0.00	2.83
Mean	5.77	15.35	11.13	32.25

It can be seen that the most abundant radio-nuclide in all the samples analyzed is Potassium (K-40), reason because K-40 is the seventh most abundant element in the earth's crust and the sixth most abundant in the ocean. It is present in mineral waters. Potassium is an important constituent of fertile soil and is an essential nutrient for plant growth and in the human diet.

Total annual effective dose Ed (Sv/y)

The total annual effective dose Ed (Sv/y) estimation for an individual due to the ingestion of the natural radionuclides present in food drinks samples was done using equation 2.

Radionuclide ingested dose conversion factors for different age groups were developed by IAEA (1996) and are shown in Table 2. It was observed that the mean total annual effective radionuclide dose ranged from 2.83 µSv y^{-1} from pure water to 60.86 µSv y^{-1} in 7-Up. The mean value of the total effective dose equivalent is 32.25 µSv y^{-1}. This value is lower than the 0.1mSv $y^{-1}$and 1.0mSv y^{-1} recommended by WHO and NCRP respectively (WHO, 2003; NCRP, 1993).

The Excess Lifetime Cancer Risk

The excess lifetime cancer risk (ELCR) for outdoor exposure, which deals with the risk of developing cancer over a period of time due to the ionizing radiation emitted by the radionuclides in the study area was calculated using equation 3. The mean excess lifetime cancer risk (ECLR) of 1.13 x 10^{-4}. This value is lower than the world average of 2.9 x 10^{-4} (UNSCEAR 1988). The result shows that there are little or no significant health risks to humans as a result of consumption of the analyzed food drinks.

However, long-term exposure to radiation is assumed to have some risks of causing cancer. The implication is that every individual has a risk of getting cancer at a time in his lifetime in varying degrees of probability.

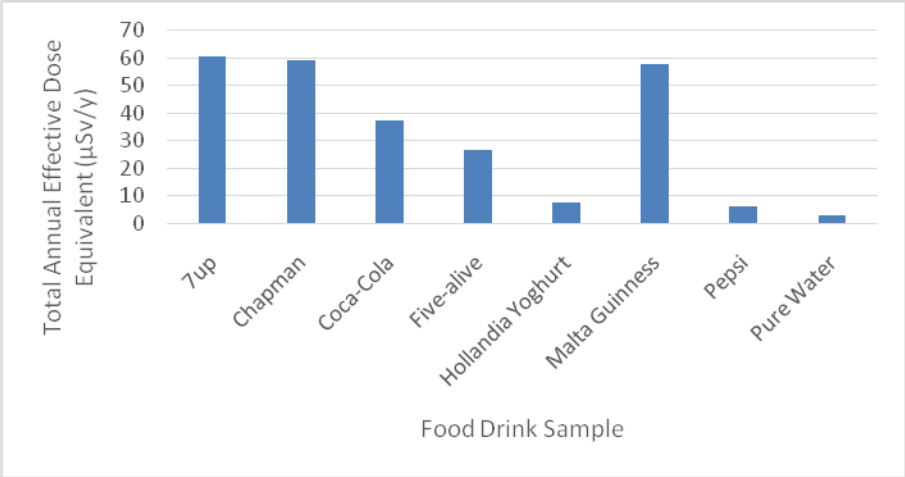

Figure 2 Total effective dose of each Drink samples in (µSy)

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Conclusion

The activity concentration obtained for the drink samples using gamma ray spectrometry analysis gave a natural radiometric survey of the drink samples in Akure and its environs. The results is lower than the permissible limit. The results showed that the concentration values of specific activities of the drink samples collected from Akure and its environs, were estimated to be relatively within the acceptable limits with arithmetic mean of 23.76±1.57Bq/L, 0.78±0.16Bq/L, and 1.55±0.11Bq/L for ^{40}K, ^{238}U, ^{232}Th respectively.

The mean excess lifetime cancer risk (ECLR) of 1.13 x 10^{-4} obtained in the research is lower than the world average of 2.9 x 10^{-4} (UNSCEAR 1988), which implies that there are little or no significant health risks to humans as a result of consumption of radionuclides from the analyzed food drinks. Long-term exposure to radiation is assumed to have some risks of causing cancer, which should be prevented to avoid over-exposure and the resultant health effects

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