



ASSESSMENT OF RADIOLOGICAL HAZARD LEVELS IN DRINKABLE WATER: A CASE STUDY OF SACHET WATERS CONSUMED IN ADEKUNLE AJASIN UNIVERSITY COMMUNITY AND ITS ENVIRON

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ABSTRACT

Water samples, popularly known as “pure water” or “sachet water”, that are consumed in Adekunle Ajasin University, Akungba Akoko Nigeria and its environs have been collected in order to determine the activity concentrations of ^{40}K , ^{226}Ra and ^{232}Th in the samples. Measurements of radioactivity in the water samples were carried out using γ -ray spectroscopy. A total of twenty one “pure water” samples from five towns close to Adekunle Ajasin University Akungba Akoko, were collected for study. The mean total annual ingestion effective doses evaluated from the measured activity concentrations of the radionuclides in these samples were found to be $48.34 \pm 12.15 \mu\text{Svy}^{-1}$ and ranged between 24.11 ± 6.37 and $64.89 \pm 16.35 \mu\text{Svy}^{-1}$. The overall annual ingestion effective dose from all measured radionuclides was below World Health Organization (WHO) recommended reference level of $100 \mu\text{Svy}^{-1}$ for all water samples. Thus, the water samples analyzed in this study are radiologically safe for drinking and domestic use. The result obtained in this study, has been taken as baseline for activity concentrations of natural radionuclides in drinking water samples within Akungba-Akoko Community.

Keyword: Water, gamma spectrometry, radionuclide, activity concentrations.

INTRODUCTION

Exposure of humans to ionizing radiations that are known to be harmful to health can not be detected with unaided sense. The degree of radiation hazard to man depends on the level of ionizing radiation that a man is exposed to. Ionizing radiation exists in the atmosphere because of contributions of both primordial radioactive elements and their decay products in the earth (mainly ^{238}U , ^{232}Th , ^{40}K), and extra terrestrial cosmic radiation in the soil and rock (UNSCEAR, 1982; Tso and Li, 1987).

The major means in which the naturally occurring radioactive materials enter the human body are through two main pathways: by inhalation of radioactive gas

like radon and ingestion of primordial radionuclides as well as their radioactive progenies. The decay of inhaled or ingested radionuclides gives rise to internal exposure of the tissues and organs in the human body (Ajayi and Adesida, 2009; Nworgu and Bamidele, 2011; Ramachandran, 2011; Yussuf, 2012).

About 70 - 75% of total body weight is made up of water and that invariably makes water the most important source for life. The 70% of the world's surface is covered by water. However, only 0.3 % of these are drinkable and suitable for daily use. The greater percentage of this drinkable water is sourced from surface water and ground water. Included in earth-sourced water are many

dissolved compounds and minerals in which radioactive substances are incorporated. This is made possible as the water passes through rock and soil formations. This therefore makes ground water to be more radioactive than surface water (Akar et al., 2012). Another important issue is that radiological toxic water can not be sensed by human, since it is odorless, tasteless and colorless.

The importance of water as essential commodity without which there is no life has made World Health Organization (WHO) to recommend safe radiological hazard levels for various drinking water in its general guidelines. Most countries in developed world have been using these guidelines to formulate their own national water quality guidelines (Chech et al., 1987; Chech et al., 2008; Finkelstein and Kreiger 1995; Fuortes et al., 1990; Hess et al., 1985; Hickey and Campbell, 1968; Hirunwatthanakul et al., 2006; Hudak 1999; Hudak 2004). The National Agency for Food and Drug Administration and Control (NAFDAC) is in charge of formulating and enforcing bottled and sachet drinking water quality standards in Nigeria. However, their standards only focus on the physico-chemical parameters and microbiological contaminants that could especially generate water borne diseases without being cognizant of the lethal health risks associated with radioactive contaminants (WHO 1996; 1998; Garba et al 2008; Ajayi and Adesida, 2009; Tchokossa 2011)

The greater parts of Nigerian populace do not have access to pipe born water. As a result of the increasing alertness of possible health risk related to intake of unsafe or untreated drinking water, most Nigerian to prefer either sachet or bottled water. However, most sachet and bottled water are sourced from ground water that is prone to radiological contamination. Sachet water is mostly demanded because it is relatively inexpensive as compared with bottled water. In the light of

these, it is necessary to determine radiation levels in sachet water in order to assess their radiological safety for drinking and domestic use. Generally, gamma ray spectrometric technique has been a conventional method for determination of radiation levels in any material of interest (Eisenbud and Gesell, 1997; Hamby and Tynybekov, 2002; Tzortzis et al., 2003; Bastos et al., 2005). This technique has been widely employed in determination of radiation levels or radionuclide concentrations in various minerals and other samples, ranging from water (Tchokossa et al., 1999; Fredj et al., 2005), foods and the environments (IAEA, 1989). This study was undertaken with an objective to determine the level of radiological hazards in sachet waters consumed in Adekunle Ajasin University community, Nigeria.

METHODOLOGY

Sample collections and preparation

Twenty one different brands of sachet water identified by names of the manufacturers were collected from Adekunle Ajasin University Akungba Akoko, and from some towns not farther than 100km away from it, in Ondo State, Nigeria. Samples numbers and addresses/locations of production are presented in Table 1. Half a liter of each of the sachet waters were put in plastic containers of uniform sizes. The containers were sealed up to have them shielded hermetically and also shielded externally to ensure that all daughter products of uranium and thorium in particular do not escape. A time of 4 weeks was allowed after packing, which was sufficient time required to attain a state of secular radioactive equilibrium after progeny (Ajayi et al., 2007). It was ensured that the calibration standard reference samples used for the detector efficiency calibration, represented the samples to be counted. The sample has similar matrix with the water samples counted at the spectrometer setting given from the standard recommendation.

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Table 1. Names, locations and addresses of sources of the water samples.

S/N	SAMPLES	ADDRESSES
1	BENIN OWENA	Alagbaka Road, Opp. Nitel, Akure
2	CHIVA	2, Olajugba Quarters, off Ilesha Road, Akure
3	EPUDORM	Km 5, Akure-mafon Rd., akure
4	FEMNIK	Km 4, Idanre Road, Akure
5	GOYET 2	Plot 7, NTA Road, Obaile Estate, Akure
6	O'DOLA	Plot 25, Block 5, Oba-Ile Housing Estate, Akure
7	SAY CRYSTAL	22B, Alagbaka New Layout, Behind RCCG Gate Parish, GRA, Akure
8	MACK T	Ikare Akoko
9	AAUA	Akungba Akoko
10	FOLU	Ugbe Akoko
11	NKAG	Ikare Akoko
12	TITU	Akungba Akoko
13	ASIKO	Ikare Akoko
14	DAY STAR	Ugbe Akoko
15	JOY	10, Iselu Owo
16	BOSLAD	7, Ute road Owo
17	IBITOYE	54, Adetula Owo
18	OWO COOP	12, Okeogun Owo
19	OYIN	10, Okeodogbon Owo
20	BISCO	4, Okeogun Owo
21	JIM JAY	7, Iselu Owo

Radioactivity Measurement

Activity concentration measurement was carried out by employing gamma-ray spectroscopy (Osama et al., 2008). The spectrometer used was a 7.6 cm × 7.6 cm NaI (Tl) detector. It was a well-calibrated, shielded and highly efficient detector (Bircon model, serial number ff-669), coupled to a Canberra series 10 plus Multichannel Analyzer (MCA). The detector resolution measured by Full Width half Maximum (FWHM) is ~8% at the 0.662 MeV of ¹³⁷Cs peak. The detector is maintained in a vertical position in a Canberra lead cylindrical shield of 10 cm thickness. For the purpose of identifying the various radionuclides that may be present in the samples through the gamma energies they emit, energy calibration of the detector was performed using a set of International Atomic Energy Agency (IAEA) standard

sources of known radionuclides with well-defined energies within the range of interest (0.511-2.615 MeV). The water samples were transferred to a 1-L Marinelli sample container, which fits into the detector. The samples were placed on top of the detector and each sample was counted for 10 hours. The net area count under the photopeak of each of the radionuclides was computed using the firm-ware algorithm of the MCA. The ²²⁶Ra and ²³²Th activities were determined indirectly through the activities of their decay products. The choice of the reference nuclides for the activity determination was made based on the fact that the NaI (Tl) detector used in this study has a poor resolution; hence the peaks of interest to be considered would be sufficiently discriminated and intense. Therefore, the ²²⁶Ra content of the samples was determined from the intensity of the

1.760 MeV gamma-ray peaks of ^{214}Bi , the ^{232}Th content from the intensity of the 2.615 MeV gamma-ray peak from ^{208}Tl , and the ^{40}K content from 1.460 MeV gamma-ray peaks following the decay of ^{40}K . The net area count after background corrections in each photopeak was used to compute the activity concentration of each of the radionuclides in the samples via the Equation (1) (Awodugba and Tchokossa 2008; Ajayi and Achuka, 2009):

$$A_c (\text{Bq} \cdot \text{L}^{-1}) = \frac{AA_c^5 M_v^5}{A^5 M_v} \quad (1)$$

where A_c = activity of sample, A = full peak area of samples, A^5 = activity concentration of the radionuclide in the standard sample ($\text{Bq} \cdot \text{L}^{-1}$), M_v^5 = Volume of standard sample (L), A^5 = full peak area of the standard sample and M_v = is the volume of the sample (L).

Radiological Evaluation

The parameters required to estimate the equivalent dose to members of the public from the ingestion of radionuclides in drinking water are the concentration of the radionuclides in water (measured in $\text{Bq} \cdot \text{L}^{-1}$), the daily consumption rate of water ($\text{L} \cdot \text{d}^{-1}$), and the dose conversion factor for each particular radionuclide. These parameters allow for the annual dose from each individual radionuclide consumed in water to calculate annual ingestion effective dose (AIED) using the following equation:

$$\text{AIED} (\mu\text{Sv} \cdot \text{yr}^{-1}) = \sum (\text{IxDxA}) \quad (2)$$

where I is the dose per unit intake ($\text{mSv} \cdot \text{Bq}^{-1}$), D is the annual water consumption ($\text{L} \cdot \text{y}^{-1}$) and A is the radionuclide concentration in ($\text{Bq} \cdot \text{L}^{-1}$). Dose per unit intake by ingestion for adult members of the public was obtained from International (ICRP, 2012) while yearly consumption of water for an individual is assumed to be $890 \text{ L} \cdot \text{y}^{-1}$ (Osama et al., 2008).

RESULTS AND DISCUSSION

The activity concentrations measured in all the understudied water samples are presented in Table 2. As can be observed in the table, Cesium-137 was not detected at all in any of

the samples. This is an indication that the radioactivity in the collected samples was only due to natural radioactive elements. This was expected, since there have not been nuclear installations in the study area that could have been responsible for possible presence of artificial radionuclide in the water samples. A similar report of absence of artificial radionuclide in all water samples from the Odeda and Obafemi-Owode areas in Ogun State Nigeria was reported by Jibiri et al., 2010.

The range and the mean activity concentrations of ^{40}K in all the water samples were 4.23 ± 1.13 – $11.47 \pm 2.89 \text{ Bq/L}$ and $8.51 \pm 2.15 \text{ Bq/L}$ respectively. Similar values obtained for ^{226}Ra were 0.019 ± 0.008 – $1.95 \pm 0.81 \text{ Bq/L}$ and $0.85 \pm 0.76 \text{ Bq/L}$ while 0.024 ± 0.01 – 0.61 ± 0.0 Bq/L and $0.027 \pm 0.19 \text{ Bq/L}$ were the corresponding values obtained for ^{232}Th . As seen in Table 2 and Figure 1, the activity concentration of ^{40}K was higher than the corresponding values obtained for ^{226}Ra and ^{232}Th by factor of 10 and 315 respectively. The higher activity concentration of ^{40}K is expected, because findings have shown activity concentration of ^{40}K to be always higher than those of ^{226}Ra and ^{232}Th (Eisenbud and Gesell., 1997; Malczewski et al., 2004; Pavlidou et al., 2004). The reason for this is not far from the abundance of ^{40}K in nature as compared with other radionuclide. However, the concentration of ^{40}K recorded in JIMJAY water which has highest concentration of $11.47 \pm 2.89 \text{ Bq/L}$, is far below $185.72 \pm 16.61 \text{ Bq/L}$ reported for boreholes water in Odeda and Obafemi-Owode areas in Ogun State Nigeria (Jibiri et al., 2010). The other two radionuclide (^{226}Ra and ^{232}Th) activity concentrations were below detection limit (BDL) in many of the water samples.

The overall activity concentrations observed in all the water samples seem not to pose significant radiological hazard on health. Notwithstanding, it is necessary to verify this by evaluating the ingestion effective dose arising from their activity concentrations.

The total annual ingestion effective doses

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Table 2. Activity Concentrations and Annual Ingestion Effective Dose (AIED) of natural radionuclide in the sachet water consumed in AAUA community and environ.

S/N	SAMPLES	Activity Concentrations			Annual Ingestion Effective Dose (AIED)			TOTAL ($\mu\text{Sv/yr}$)
		^{40}K (Bq/L)	^{226}Ra (Bq/L)	^{232}Th (Bq/L)	^{40}K ($\mu\text{Sv/yr}$)	^{226}Ra ($\mu\text{Sv/yr}$)	^{232}Th ($\mu\text{Sv/yr}$)	
1	BENIN OWENA	9.98±2.54	1.16±0.52		56.46±14.39	0.12±0.05		56.58±14.44
2	CHIVA	7.81±1.99	0.10±0.05	0.61±0.14	44.17±11.25	0.01±0.00	0.72±0.16	44.90±11.41
3	EPUDORM	8.89±2.28		0.53±0.12	50.32±12.91		0.62±0.14	50.94±13.05
4	FEMNIK	6.45±1.11	1.30±0.28	0.43±0.07	36.50±6.26	0.13±0.03	0.52±0.08	37.15±6.37
5	GOYET 2	11.07±2.84			62.61±16.08			62.61±16.08
6	O'DOLA	8.21±2.06		0.36±0.08	46.45±11.64		0.43±0.10	46.87±11.73
7	SAY CRYSTAL	6.21±1.64	0.54±0.24	0.10±0.02	35.14±9.30	0.05±0.02	0.12±0.03	35.31±9.35
8	MACK T	7.65±2.00		0.25±0.06	43.26±11.31		0.30±0.07	43.56±11.38
9	AAUA	5.98±1.49		0.18±0.05	33.85±8.43		0.22±0.05	34.07±8.49
10	FOLU	10.66±2.71			60.33±15.35			60.33±15.35
11	NKAG	4.44±1.20			25.12±6.81			25.12±6.81
12	TITU	9.08±2.33		0.09±0.02	51.38±13.17		0.10±0.02	51.48±13.20
13	ASIKO	11.05±2.69			62.54±15.20			62.54±15.20
14	DAY STAR	10.03±2.51		0.12±0.03	56.77±14.21		0.14±0.03	56.90±14.24
15	JOY	9.18±2.39		0.02±0.01	51.91±13.52		0.03±0.01	51.94±13.53
16	BOSLAD	8.69±2.17	0.02±0.01	0.39±0.09	49.18±12.30	0.00±0.00	0.46±0.11	49.64±12.41
17	IBITOYE	7.18±1.80	1.95±0.81		40.60±10.16	0.20±0.08		40.80±10.24
18	OWO COOP	9.47±2.39			53.58±13.53			53.58±13.53
19	OYIN	10.95±2.73			61.93±15.43			61.93±15.43
20	BISCO	4.23±1.14		0.17±0.04	23.91±6.44		0.20±0.05	24.11±6.48
21	JIM JAY	11.47±2.89			64.89±16.35			64.89±16.35
22	WHO (1997)							100

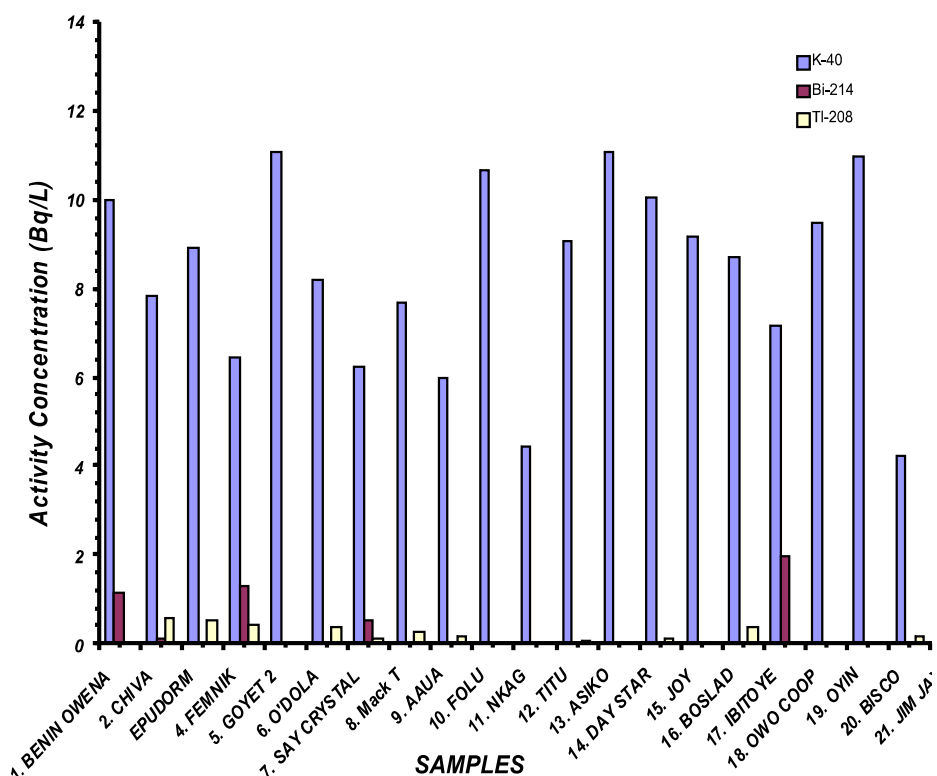


Figure 1: Concentration of natural radionuclides in the sachet water consumed in AAUA community and environ.

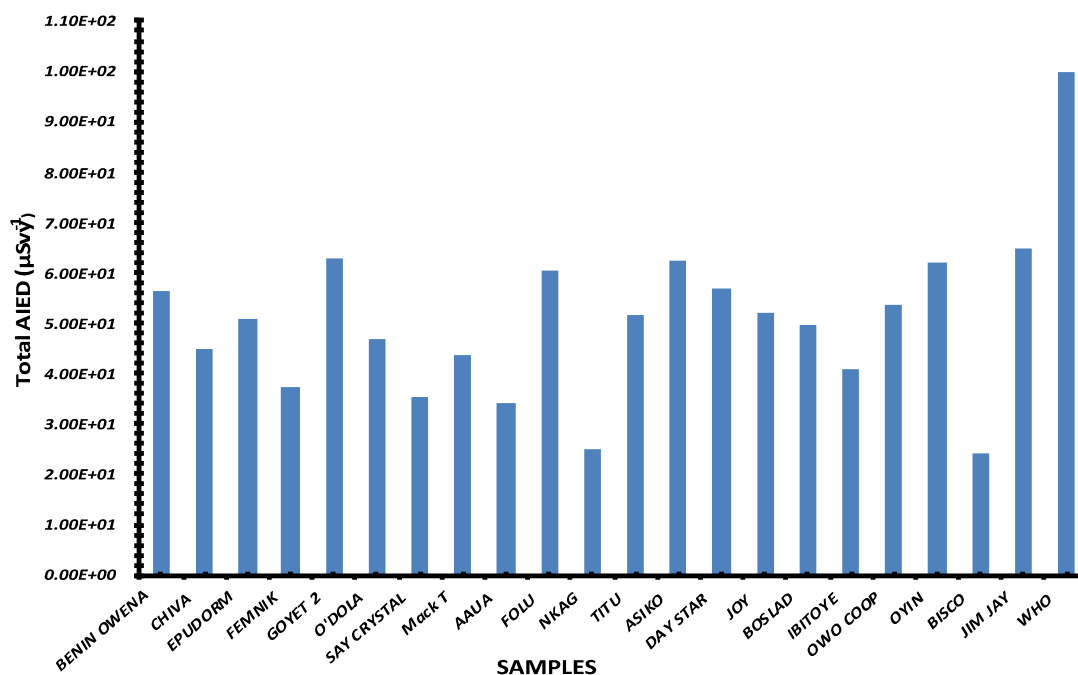


Figure 2: Calculated total annual ingestion effective doses (AIED) in sachet water consumed in AAUA community and environ.

(AIED) were evaluated using equation (1) above from the measured activity concentrations of the radionuclides in all the water samples. The amount of total AIED calculated in each water samples corresponds to the degree of the activity concentrations in each of them. These are shown in Table 2. As expected, JIMJAY water tops the list of samples with the highest level of total AIED, being the one already noted with the utmost radionuclide. AIED $64.89 \pm 16.35 \mu\text{Svyr}^{-1}$ was calculated for this sample while $24.11 \pm 6.37 \mu\text{Svyr}^{-1}$ was evaluated for BISCO water as the sample with the least radioactivity. For better illustration, the total AIED for all the water samples are comparatively shown in figure 2. The interesting inference drawn from this study is that all the total AIED calculated in each of the samples are well below the WHO 1997 recommended reference level of $100 \mu\text{Svyr}^{-1}$.

CONCLUSION

The gamma-ray spectrometric methods have been used to determine the natural radionuclide concentrations in sachet waters consumed in Adekunle Ajasin University community and its environ. The average total annual ingestion effective doses in all the 21 water samples were found to be $48.34 \pm 12.15 \mu\text{Svyr}^{-1}$ and they ranged between 24.11 ± 6.37 and $64.89 \pm 16.35 \mu\text{Svyr}^{-1}$. The overall annual ingestion effective dose from all measured radionuclides was below World Health Organization (WHO) recommended reference level of $100 \mu\text{Svyr}^{-1}$ for all water samples. Therefore, the water samples analyzed in this study are radiologically safe for drinking and domestic use. The result obtained in this study, has been taken as baseline for activity concentrations of natural radionuclides in drinking water samples within Akungba-Akoko Community and its environ. This investigation is recommended to be extended to more sources of drinking water and those used for domestic purposes, like well water and boreholes.

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