Gamma Radioactivity Measurement in Commercially-Available Drinkable Water In Lagos, South Western Nigeria

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Abstract

In this work, gamma spectroscopy measurements of twenty commercially- available drinkable sachet and bottled waters within Lagos metropolis was carried out to determine the activity concentration of K-40, Th-232 and U-238 radionuclides in them. Measurement was done using a well calibrated NaI (Tl) and well shielded detector coupled to a computer resident quantum MCA2100R Multichannel analyzer. The mean activities (Bqm^{-3}) in the sachet water samples ranged between 80.13 ± 20.01 to 101.12 ± 40.12, 10.13±4.20 to 12.21±2.40 and 9.10±1.12 to 10.42±2.13 respectively for K-40, U-238 and Th-232. In the bottled water, the range of the activity (Bqm^{-3}) for K-40, U-238 and Th-232 was between 70.48±39.28 to 100.09±60.16, 9.19±3.01 to 12.80±2.37 and 8.18±3.34 to 10.93±5.43 respectively. The computed mean annual doses (μSv) for the radionuclides investigated in the sachet water and bottled water was 0.972 and 0.974 respectively. All the samples had activity concentrations that were below the WHO guideline levels for the investigated radionuclides. Their annual ingestion doses were very well below the recommended limit of 0.1mSv thus posing no immediate health threats when they are consumed.

1. Introduction

Water is an essential component for life and an important source of intake of trace elements in humans [1]. It moves continually through the cycle of evaporation, transpiration (evapotranspiration), condensation, precipitation, and runoff, usually reaching the sea. All living things require water to grow and reproduce. Agricultural, industrial, household, recreational and environmental activities all require the use of water. While 70% of the world's surface is covered by water, only 0.3 % of the total water resources on earth is drinkable and suitable for daily use [2]. Drinkable water usually contain several natural radionuclides: tritium, radon, radium, uranium isotopes, etc.; their concentrations largely depending on the nature of the aquifer, namely, the prevailing lithology and whether there is air in it or not [3]. These radionuclides are members of three natural radionuclide series – uranium series, thorium series and the actinium series. Isotopes of radium, derived from the U-228, U-235 and Th-232 decay chains are carcinogenic [4], [5], [6] and therefore their occurrence in drinkable water above recommended safe limit may increase the long-term incidence of cancer. Radium - 226 and Ra-228 in particular are readily soluble in water and travel easily within the aquifer [7]. In addition, they are highly radiotoxic and dangerous in case of ingestion, having much similarity in behavior to calcium commonly fixed in bones [8].

According to the World Health Organization's report [9] safe drinkable water is water that "does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages". Such water, among other essential characteristics must be colourless, odourless, tasteless, free from faecal pollutions and of pH. range between 6.5 -9.5

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[10], [11]. In addition, the radionuclide concentrations in such water are not expected to be above accepted guidance level [12].

The human body contains from 55% to 78% water, depending on body size. To function properly, it requires between one and seven liters of water per day to avoid dehydration; the precise amount depending on the level of activity, temperature, humidity, and other factors [13]. In order to meet this demand, individuals resort to consuming commercially -available drinkable water while on transit, at workplace or in other places apart from their homes. Even in several homes, commercially –packaged water have replaced municipal water supplies, where the latter is not readily available.

In Lagos, consumption of sachet and bottled water has widely increased in recent years. This partly is due to growing awareness that the consumption of unsafe or untreated water is the cause of many diseases especially water borne diseases. Commercially - packaged sachet and bottled water have a wide patronage because of their ready accessibility and relatively low cost. Such water, which are generally advertised as 'pure water' are derived from underground water supply through dug-wells and boreholes. Consequently, they contain dissolved minerals, microorganism and radionuclides prior to treatments. The extent to which these underground water are treated before they are packaged for sales and public consumption cannot be ascertained for all the available brands of drinkable water. Some factors which may be contributory to the poor or no treatment of several of these packaged water include: non-availability of required water- treatment facilities, malfunctioning or breakdown of equipment for water treatment, cutting of cost, weak implementations of water treatment regulations *vis-a-vis* meting out appropriate sanctions on defaulters, etc. The public who consume the water, without the mindfulness of the extent of its safety is at the receiving end, and could via the ingestion pathway become exposed to ionizing radiation, among other contaminants that could be contained in such water.

This research therefore seeks to ascertain the radiological safety of commercially - available drinkable sachet and bottled water within Lagos metropolis by determining the ingestion dose from the consumption of such drinkable water and the attendant radiation risks.

2. Materials and Methods

The study was carried out within Lagos metropolis.

2.1 Sample Collection and preparation

Ten samples each of sachet and bottled water were randomly purchased at different sales point, after it was established that their expiry dates were not exceeded. These included both the popular brands of sachet and bottled water as well as those that may have not gained a wide recognition among consumers. The samples were emptied into 35cl Marinelli containers that had been earlier rinsed with dilute HCl to prevent absorption of radionuclides by the walls of the containers. The samples were thereafter sealed and transferred to the laboratory at the Department of Pure and Applied Physics, Ladoke Akintola University of Technology, Ogbomoso for gamma spectrometry analysis.

2.2 Gamma ray spectrometry

The gamma spectrometry set up comprised a well calibrated NaI (TI) and well shielded detector coupled to a computer resident quantum MCA2100R Multichannel analyzer. An empty container of the same geometry as those of the containers containing the sealed water samples was placed inside the chamber containing the detector. Thereafter the water samples were counted. Each sample counting was done for 36000 seconds (10 hours). The net count was obtained by subtracting the background count (measurement of an empty marinelli container) from the total count of the sample and container. The gamma transition energy of 1764.5KeV, Bi-214 was used to determine the concentration of U-238 while the gamma transition energy of 2614KeV TI-208 was used to determine the concentration of Th-232. The K-40 activity concentration was determined directly from its emission line at 1460.8 keV.

The efficiency calibration of the detector was done using a reference standard mixed jelly source

traceable to Analytical Quality Control Service (AQCS, USA), which has certified activities of the selected radionuclide and has a geometrical configuration identical to sample container. The standard sources contained ten known radionuclide. The energy calibration was also performed by using the peaks of the radionuclide present in the standard sources.

3. Results and Discussions

3.1 Radioactivity concentrations in water samples

The radioactivity concentration in the water samples are shown in Table 1

The activity concentrations of K-40 was higher in all the sampled sachet and bottled water compared to the other two radionuclides of interest. Its least value of 70.48± 39.28 Bqm^{-3} is greater than the highest concentration levels of Th-232 and U-238 in all the samples by factors of 5.5 and 7.7 respectively. The natural abundance of K-40 in the earth's crust and its ready solubility in its compound form in water as reported by Ajayi and Achuka [14] may account for its high concentration in the water samples. Darrey sachet water had the highest concentration of K-40 in all the samples. Thorium -232 concentration is fairly uniform in most of the sachet water. Its least and greatest concentrations of 8.18 ± 3.34 Bqm^{-3} and 10.93 ± 5.43 Bqm^{-3} are however found in Cway and Skord bottled waters respectively. Uranium -238 concentration was same in Evetee sachet water and Aquapoint bottled water, where it recorded the highest activity of 12.80 ± 2.37 Bqm^{-3}. Its least value of 9.19 ± 3.01 Bqm^{-3} was found in Eva bottled water. The appreciable variations in the concentration levels, particularly of Th-232 and U-238 in the water samples suggests that the treatment for radionuclides in the samples by the various producers of the packaged water may not follow uniform or standard procedures in all cases.

The mean values (Bqm^{-3}) of U-238, Th-232 and K-40 in the sachet and bottled water are 11.27± 2.61, 9.38 ±1.89, 95.53 ± 28.54 and 10.67± 4.06, 9.50 ± 2.85, 87.04± 38.63 respectively. These values are within the range of those reported for bottled water in two cities in Pakistan [15]. They are however much lower than those reported in sachet water in both Ilorin [6] and Akure [16]. According to the WHO report [17], the guideline levels of U-238 and Th-232 activities in drinkable water are 1Bq/L (1000 Bqm^{-3}) and 0.1Bq/L (100 Bqm^{-3} respectively. All sachet and bottled waters sampled in this work are much lower than the guideline levels for both radionuclides.

Table 1: The Radioactivity concentration in water samples

	SAMPLE	*K-40 (Bq/m^3)*	*U-238 (Bq/m^3)*	*Th-232 (Bq/m^3)*
Sachet water	VIRGO GAY	80.13 ± 20.01	10.17 ± 1.01	9.10 ± 1.12
	DARREY	101.12 ± 40.12	12.21 ± 2.40	10.12 ±1.43
	BAMAS	98.23 ± 45.17	11.03 ± 2.25	9.12 ± 2.16
	MOSROT	96.10 ± 30.10	10.35 ± 1.21	9.23 ± 3.20
	ICE SOURCE	95.12 ± 27.03	10.97 ± 1.51	9.20 ± 1.28
	MUSLARI	86.32 ± 17.21	12.24 ±3.75	9.14 ± 2.03
	AQUAPOINT	100.21 ± 29.22	11.05 ± 2.13	9.13 ± 1.09
	EVETEE	85.21 ± 12.10	12.80 ± 2.37	10.42 ± 2.13
	UTMOST	98.10 ± 25.16	10.13 ± 4.20	9.19 ± 2.10
	MANDA	99.40 ± 39.28	11.76 ± 5.28	9.18 ± 2.34
Bottled water	EVA	84.16 ± 30.01	9.19 ± 3.01	9.13 ± 2.08
	SKORD	100.09 ± 60.16	10.61 ± 6.40	10.93 ± 5.43
	MR. VEE	78.38 ± 45.07	12.13 ± 4.95	9.42 ± 3.16
	AQUARITE	98.37 ± 30.10	9.35 ± 1.91	9.03 ± 3.24
	NIRVANA	95.22 ± 47.03	9.97 ± 3.57	9.22 ± 1.38
	BIGI	76.32 ± 47.41	10.24 ± 3.75	9.14 ± 4.09
	ALARIS	90.60 ± 39.22	11.05 ± 5.19	10.13 ± 1.09
	AQUA POINT	85.61 ± 22.15	12.80 ± 2.37	10.42 ± 2.33
	BOBID	91.14 ± 25.86	10.13 ± 4.20	9.39 ± 2.40
	CWAY	70.48 ± 39.28	11.20 ± 5.28	8.18 ± 3.34

3.2 Evaluation of Annual radioactive Dose in drinking water

The annual ingestion dose in the water samples was obtained using equation 1 [18]:

$$E_{avg} = \sum_i A_i * DCF_i * 730 \quad (1)$$

where A_(i) is the activity concentration of individual radionuclides

present in the water sample and DCF_i is the dose conversion factor for ingestion of the individual natural radionuclides for an adult.

The conversion factor or dose per unit intake by ingestion of naturally occurring radionuclides for adult members of the public used were: 4.5 x 10-5 mSvBq-1 for 238U and 2.3 x 10-4 mSvBq-1 for 232Th [19]. Potassium -40 does not accumulate in the body but is maintained at a constant level independent of intake [12], therefore the ingestion of K-40 may not be harmful to the body since it has little effect on the body content or on the radiation dose received [20]. Consequently, K-40 is not used in the computation of committed effective dose received by the ingestion of the sampled water in this study. A daily water intake of 2 litres/day is assumed [21] thus resulting in annual consumption rate of 730 litres/year, which is equal to 0.73 m^3 y^{-1}.

The annual ingestion dose from the consumption of the sachet and bottled water is presented in Table 2. The ingestion doses due to Th-232 is higher than those due to U-238 in all the samples, following its higher dose per unit intake which is higher than that of U-238 by an approximate factor of 5 [19]. The contribution to the ingestion dose (µSv) from U-238 and Th-232 in the sachet water ranged between 0.33 to 0.42 and 1.53 to 1.75 with mean values of 0.39 and 1.54 respectively. In the bottled water samples, the ingestion dose (µSv) contributions were 0.30 to 0.42 and 1.37 to 1.84 with mean values of 0.35 and 1.60 in U-238 and Th-232 respectively. The mean values of ingestion dose due to U-238 and Th-232 in this work are lower than those obtained for drinkable water in Samsun, Turkey [7].

Table 2: Annual ingestion dose (µSv) from drinkable water samples

SAMPLE		*U-238*	*Th-232*
Sachet water	VIRGO GAY	0.33	1.53
	DARREY	0.40	1.70
	BAMAS	0.36	1.53
	MOSROT	0.34	1.55
	ICE SOURCE	0.36	1.54
	MUSLARI	0.40	1.53
	AQUAPOINT	0.36	1.53
	EVETEE	0.42	1.75
	UTMOST	0.33	1.54
	MANDA	0.39	1.54
Bottled water	EVA	0.30	1.53
	SKORD	0.35	1.84
	MR. VEE	0.40	1.58
	AQUARITE	0.31	1.52
	NIRVANA	0.33	1.55
	BIGI	0.34	1.54
	ALARIS	0.36	1.70
	AQUA POINT	0.42	1.75
	BOBID	0.33	1.58
	CWAY	0.37	1.37

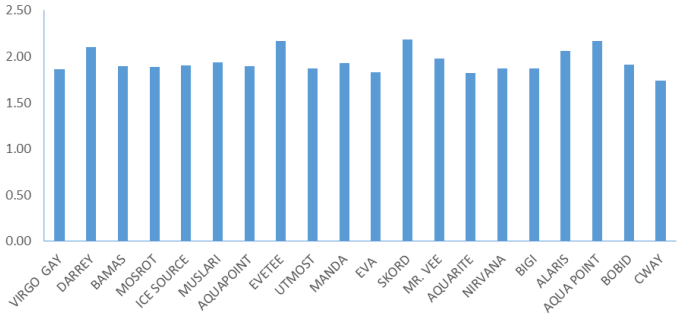

Figure 1: Total annual ingestion dose (µSv) in the sachet and bottled water samples

Figure 1 gives the distribution of the total annual ingestion dose (excluding contributions from K-40) in all the water samples. The range of value falls between 1.74 µSv and 2.18 µSv, with mean values being 0.972 µSv in sachet water and 0.974 µSv in bottled water. The highest annual ingestion dose was recorded in Skord bottled water. Aqua point bottled water and Evetee sachet water come behind Skord water with an annual ingestion dose of 2.17 µSv apiece. The least ingestion dose is obtained in Cway bottled water.

All sampled commercially-available drinkable water had total annual ingestion dose which are much lower than the recommended reference dose levels of 0.1 mSv [17].

4. Conclusion and Recommendation

The activity of K-40, U-238 and Th-232 in twenty

commercially-available drinkable bottled and sachet water in Lagos were measured using a gamma spectrometry set -up. Their corresponding ingestion doses were computed following an annual intake of 730litres of water. All sampled water pose no radiological risk when consumed by the public as both activity concentrations of radionuclides in them and ingestion dose arising from their intake were below the recommended guideline levels. Additional work on the physico-chemical properties of the commercially-packaged drinkable water is strongly recommended in addition to the radioactivity tests which have been carried out in order to ascertain the safety of the water for public consumption.

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