





## MEASUREMENT OF RADON-222 CONCENTRATION LEVELS IN BRANDS OF SACHET DRINKING-WATER PRODUCE IN DUTSIN-MA LOCAL GOVERNMENT AREA (LGA) OF KATSINA STATE, NIGERIA



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### ABSTRACT

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The purpose of this study is to measure the concentration levels of radon-222 from seven (7) water samples collected at different sachet drinking-water companies located within Dutsin-Ma LGA using Liquid Scintillation Counter. The levels of radon-222 found to range from (11.69 **Bq/L** to 13.04 **Bq/L**), and (9.23 **Bq/L** to 11.19 **Bq/L**) with mean values of 12.37 **Bq/L** and 10.18 **Bq/L** for borehole and earth-dam sources respectively. The results found are compared with the world average maximum contaminant level (MCL) of 10 **Bq/L** set by WHO and it was discovered that 86% of the samples are below the value and 100% of the samples are below the WHO recommended reference level of 100 **Bq/L**. Annual effective doses due to ingestion of radon in water for three (3) categories of people were estimated from the measured radon concentrations and their mean values were found to be (0.090, 0.181 and 0.632) **mSv/yr** in borehole water and (0.074, 0.149, and 0.520) **mSv/yr** in surface water (earth-dam) for adults, children and infants respectively. Most of the mean values of the annual effective doses were below the recommended level of 0.1 **mSv/yr** set by WHO. Therefore, it is recommended that the inhabitants of Dutsin-Ma LGA should always drink the sachet water produce by the companies irrespective of its source.

**Contribution/ Originality:** This research used the method and equation adopted by ASTM (1999) with treated sachet water and it shown that the level of radon-222 has reduced due to the treatment and filtration given to the water, as such it is recommended that the inhabitants should always use the sachet water for drinking purposes.

## 1. INTRODUCTION

Water is the most abundant substance on earth and the principal constituent of all living things. It existed long before man came into existence. Man uses water for many purposes in areas such as agriculture, power generation and above all for domestic purposes. Water for human consumption should be free from chemical, microbiological and radiological contamination. But unfortunately in developing countries like Nigeria most people are not opportune to have access to such safe drinking water [1].

For instance, Dutsin-Ma LGA of Katsina state where its inhabitants rely solely on untreated groundwater sources (well and borehole) as well as surface water source. This is because there are only few available pipe born water sources and in most places where such sources are available they are not operational. The Zobe dam located in Dutsin-Ma which is intended to remediate this problem is yet to be completed by the government [2]. It is therefore important to investigate the radiological content of the sachet drinking-water produce in Dutsin-Ma LGA so as to determine its fitness for consumption.

Radon ( $^{222}\text{Rn}$ ), a neutral by-product of the radioactive decay of uranium, radium and thorium, is an alpha-emitting noble gas with a half-life of 3.825 days. Radon gas is soluble in water and consequently the gas may be incorporated into groundwater flows [3]. Radon is extracted from the volcanic deposits in which the aquifer resides, its transport taking place basically through the fissure network in the fractured system or from mantle degassing. The quantity of radon dissolved in groundwater depends on different factors such as the characteristics of the aquifer, water – rock interaction, water residence time within aquifer, material content of radium etc [4, 5].

Radon in water can follow two different paths to enter the human body. Firstly, radon in drinking-water can directly enter the human body through the gastro-intestinal tract and deliver a whole body radiation dose. Secondly, radon can escape from household water and become a source for the indoor radon, which can then enter the human body through the respiratory tract to deliver the radiation dose. Both mechanisms pose potential health hazards [6, 7].

However, in order to forestall risks of cancer among the general public, many national authorities and some international organizations [8, 9] have already adopted reference levels for radon in air and water.

This study aims to measure the concentration levels of Rn-222 in brands of sachet drinking-water produce in Dutsin-Ma LGA, Katsina state. The work will be significant to the communities around the sampled locations in their effort to access safe drinking-water.

## 2. MATERIALS AND METHOD

### 2.1. Geology of the Study Area

Dutsin-Ma is basically underlain by the Basement Complex area. The name “Dutsin-Ma” is coined from the Hausa word ‘Dutse’ meaning rock(s). The entire area is predominantly underlain by gneisses schists and the Older Granite. The rocks are about 600 million years old pre-protozoic. These old granites are known as Granite Suite [10].

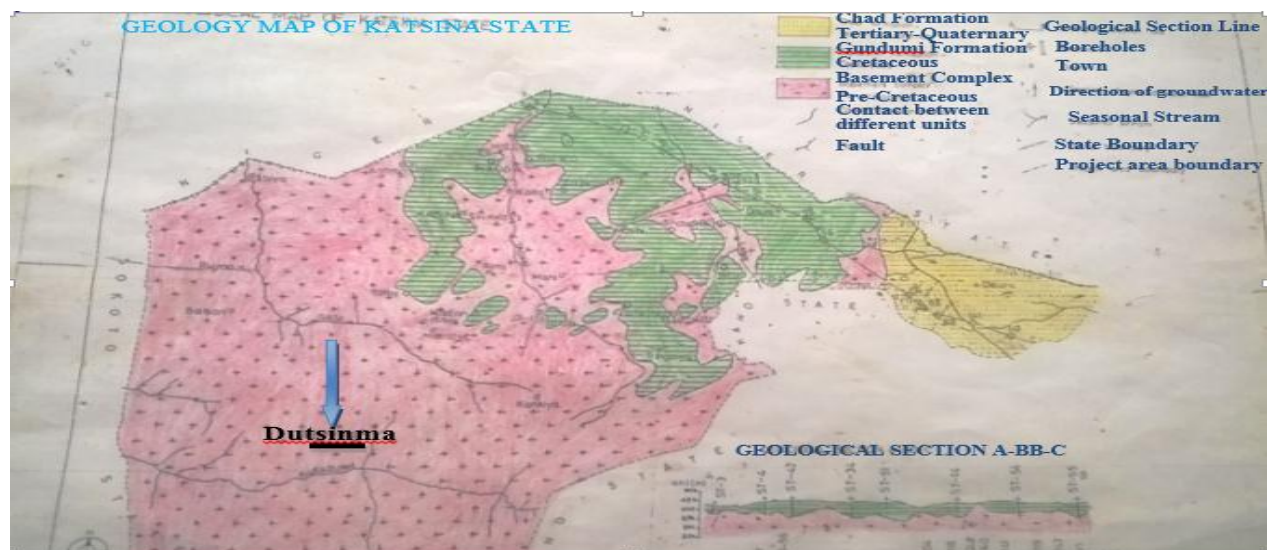


Figure-1. Geologic map of Katsina State showing Dutsin-Ma L.G.A.

Source: GEO-INVEST and BOREWELL NIG. LTD Katsina, modified.

## 2.2. Materials and Reagents

Below is the list of materials and reagents used in this research:

- (a) Disposable hypodermic syringe (20ml, 10ml capacities).
- (b) Surgical gloves.
- (c) Scintillation vials (20ml capacity) with polyethylene inner seal cap liners.
- (d) Scintillation cocktail.
- (e) Distilled water.
- (f) Indelible ink and Masking tape.
- (g) Liquid Scintillation Counter (Packard Tri-Card LSA 1000TR).
- (h) Global Positioning System (GPS).
- (i) A piece of clean cloth.
- (j) Ethanol.

## 2.3. Sample Collection

Using plastic vials, a total of seven (7) samples were collected for analysis from different sachet drinking-water companies (whose sources of water are borehole and earth-dam water) at different locations in Dutsin-Ma LGA, Katsina state. During sampling, a global positioning system (GPS) was used to mark the geographical locations (latitude and longitude) on the earth surface of the sample collection points.

## 2.4. Sample Preparation

10ml of each sample was added into a vial containing 10ml of toluene based cocktail (scintillator) using a hypodermic syringe. The vials were tightly capped and shaken vigorously for three (3) minutes to extract radon-222 in water phase into the organic scintillator. In a similar manner a blank sample for the background was prepared using distilled water that has been kept in a glass bottle for at least 21 days. The prepared samples were allowed to stand undisturbed for at least three (3) hours each in order for Rn-222 and its alpha decay products attain equilibrium before counting.

## 2.5. Sample Analysis

The prepared samples and the blank were each analysed using a liquid scintillation counter (Tri-Carb-LSA1000) at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria. Radiation emitted from the samples transferred energy to the organic scintillator which in turn emits light photons. This way each emission result is a pulse of light in form of digit [11].

The Rn-222 activity concentration was calculated using Equation 1:

$$C_{Rn-222} (BqL^{-1}) = \frac{100 \times (SC - BC) \times e^{\lambda t}}{60 \times CF \times D} \quad (1)$$

Where:

$C_{Rn-222} (BqL^{-1})$  = Concentration of Radon-222 in Becquerel per litre.

SC = Sample Count (Count  $min^{-1}$ ).

BC = Background Count (Count  $min^{-1}$ ).

t = Time elapsed between sampling to counting (minutes).

$\lambda$  = Decay constant ( $1.26 \times 10^{-4} \text{min}^{-1}$ ).

100 = Conversion factor from per 10ml to per liter.

60 = Conversion factor from minutes to seconds (*second/munite*).

CF = Calibration factor.

D = Fraction of  $^{222}\text{Rn}$  in the cocktail in a 22 ml total capacity vial for 10 ml of sample, 10 ml of cocktail and 2 ml of air.

The annual effective doses ( $\text{mSv/yr}$ ) due to ingestion of Radon-222 in sachet water samples were calculated using Equation 2 by taking into account the dose coefficient in ( $\text{Sv/Bq}$ ), the annual water consumption ( $\text{L/yr}$ ) and the activity concentration of radon-222 obtained from Equation 1 [12]:

$$E = C_{\text{RnW}} \times D \times L \quad (2)$$

Where:

$C_{\text{RnW}}$  = Concentration of radon-222, D = Dose coefficient ( $10^{-8}\text{Sv/Bq}$ ,  $2 \times 10^{-8}\text{Sv/Bq}$ ,  $7 \times 10^{-8}\text{Sv/Bq}$ ) for adults, children and infants respectively [13].

L = Annual water consumption by an adult of 2 litres per day that is 730L/yr

According to United Nations Scientific Committee on the Effects of Atomic Radiation [14] doses due to ingestion of radon in water for similar consumption rates could be factor of 2 and 7 higher for children and infants respectively.

### 3. RESULTS AND DISCUSSION

A total of seven (7) samples comprising of two (2) groundwater (borehole) source and five (5) surface water (Earth-Dam) source were collected from the sachet drinking-water companies and analysed using Liquid Scintillation Counter. The results of the analysis obtained are shown in Table 1.

The mean values of radon-222 concentrations were found to be 12.37 and 10.18 Bq/L for borehole, and surface water (Earth-Dam) source respectively Table 1. Also using equation 2 to calculate the annual effective doses, we found the mean values of the corresponding annual effective doses due to ingestion of radon-222 in borehole water to be (0.090, 0.181 and 0.632) mSv/yr for adults, children and infants respectively. While that due to the intake of radon-222 from surface water (Earth-Dam) were found to be (0.074, 0.149, and 0.520) mSv/yr, for adults, children and infants respectively. These results shows that the mean value of radon-222 concentrations in borehole have exceeded the recommended values while that of surface water samples have not exceeded and also most of the annual effective doses due to ingestion of borehole and surface water samples have not exceeded the world average recommended values of 10 Bq/L and 0.1 mSv/yr set by the World Health Organization (WHO) [15] and World

Health Organization (WHO) [16] for radon concentration and annual effective dose due to intake of radionuclide in water respectively.

**Table-1.** Results of radon concentrations in ( $Bq/L$ ) and their corresponding Annual Effective Doses (AED) in ( $mSv/yr$ ) for sachet water samples.

Sample ID	Sample location	Latitude (N)	Longitude (E)	Elevation (m)	Rn ( $Bq/L$ )	AED ( $mSv/yr$ )		
						Adults	Children	Infants
BW1	Gangaren Wakaji	12°26'72.4"	007°30'31.0"	480	11.69	0.085	0.171	0.597
BW2	Wednesday Market	12°27'67.0"	007°29'14.6"	570	13.04	0.067	0.135	0.472
SW1	Water Board Road	12°27'75.7"	007°29'88.7"	562	9.23	0.095	0.190	0.666
SW2	Water Board Road	12°27'77.5"	007°29'77.3"	562	9.83	0.072	0.144	0.502
SW3	Shagari Low-cost	12°26'48.2"	007°29'90.3"	553	11.09	0.081	0.162	0.566
SW4	Shagari Low-cost	12°27'76.0"	007°29'85.7"	561	11.19	0.082	0.163	0.572
SW5	Shagari Low-cost	12°26'66.7"	007°29'98.5"	559	9.58	0.070	0.140	0.490

### 3.1. Boreholes Water

The results of the analysis of radon concentration for the two (2) borehole water samples collected at different sachet drinking-water companies as presented in Table 1 revealed that the concentration of radon-222 varies from 11.69  $Bq/L$  to 13.04  $Bq/L$  with a mean value of 12.37  $Bq/L$ . The maximum concentration was obtained from the water company located at Wednesday market road (BW2) while the minimum concentration was found at the company located at Gangaren wakaji (BW1) as shown in Figure 2. All the values obtained from these samples were found to be above the maximum contaminated level of 11.1  $Bq/L$  set by United States Environmental Protection Agency [17] and the world average value of 10  $Bq/L$  set by World Health Organization (WHO) [15]. The mean concentration of radon-222 was found to be lower than the recommended guideline level of 100  $Bq/L$  set by World Health Organization (WHO) [18]. However, 100% of the analyzed borehole water samples which include BW1 and BW2 were found to be below 100  $Bq/L$  in which the filtration and all the treatment tends to reduce the concentration. These high concentration of radon-222 in BW1 and BW2 water samples which can pose a threat on the health of the inhabitants of those who consume the water could be due to the geology of the area which is basically made up of granites and the concentration of radium-226 from the parent rock in the aquifer matrix.

### 3.2. Surface Water

The results obtained from the analysis of the five (5) samples collected at different water companies revealed the maximum concentration of radon in the water as 11.19  $Bq/L$  while the minimum concentration was found to be 9.23  $Bq/L$  with an average value of 10.18  $Bq/L$  as presented in Table 1. All the values obtained for the sachet water

whose source is surface water have not exceeded the maximum contaminant level of 11.1 **Bq/L** set by [United States Environmental Protection Agency \[17\]](#) although some of these water samples have exceeded the maximum contaminant level of 10 **Bq/L** and these higher values of radon in some of these surface water could be linked to the granitic rocks used in the construction of the dam bank as well as the soil type. Environmental waste flooded into the dam during heavy rainfall might also be a contributing factor. The mean concentration of radon-222 was found to be lower than the recommended guideline level of 100 **Bq/L** set by [World Health Organization \(WHO\) \[18\]](#). However, 100% of the analyzed surface water samples were found to be below 100 **Bq/L** in which filtration and all the treatment carried by the sachet water companies tends to reduce the concentration of radon in the water source.

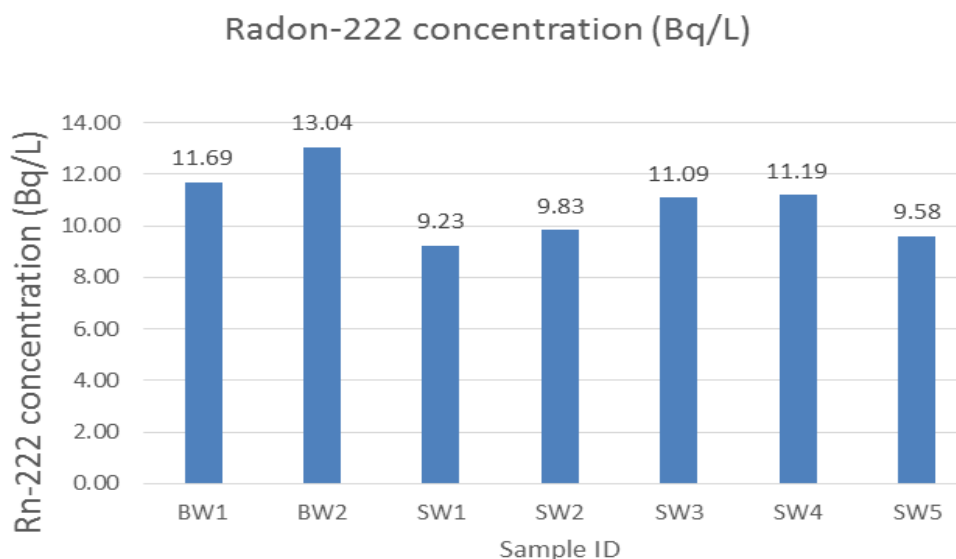


Figure-2. Bar graph of Radon-222 concentrations for both Borehole and Earth-Dam water source samples.

### 3.3. Mean Radon Concentrations

To compare the level of radon-222 in the two categories of water sources: groundwater (borehole) and surface water (Earth-Dam) collected from the sachet water companies, the mean concentration of each of the water types were calculated and plotted as shown in [Figure 3](#). Samples from borehole have the highest mean concentration of radon-222 while the surface water (earth-dam) has the least mean concentration of radon. The mean value from the borehole water types exceeded the maximum contaminant levels set by [United States Environmental Protection Agency \[17\]](#) and the world average value of 10 **Bq/L** set by [World Health Organization \(WHO\) \[15\]](#). While the Earth-Dam water is less than the maximum contaminant levels. However, the lower mean value of radon-222 concentration for surface water as compared to mean radon concentrations of borehole water could be linked to the fact that surface water is exposed to the air and since radon is a gas it tends to escape into the air; and the higher mean values recorded for the borehole water source may be due to the fact that radon dissolves in water under pressure which lead to the radon accumulation in groundwater as reported by [Cho, et al. \[19\]](#).

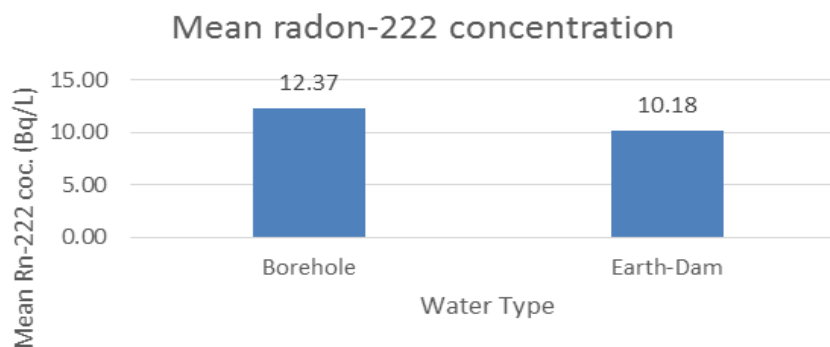


Figure-3. Bar graph of mean Radon-222 concentrations for the two water types use by the companies.

### 3.4. Annual Effective Doses (AED)

The Annual Effective Doses due to intake of radon-222 from borehole water samples collected at Dutsin-Ma LGA, Katsina state were estimated for the same water consumption rate using Equation 2 and found to range from (0.085 to 0.095) *mSv/yr*, (0.171 to 0.190) *mSv/yr* and (0.597 to 0.666) *mSv/yr* as shown in Table 1 with corresponding mean values of 0.090, 0.181 and 0.632 *mSv/yr* for adults, children and infants respectively. In a similar manner, the annual effective doses due to ingestion of radon-222 from surface water (Earth-dam) were estimated and found to range from (0.067 to 0.085) *mSv/yr*, (0.134 to 0.190) *mSv/yr* and (0.502 to 0.572) *mSv/yr* with corresponding mean values of 0.074, 0.149 and 0.520 *mSv/yr* for adults, children and infants respectively. Most of the estimated Annual Effective doses were found to be below the recommended reference level of 0.1 *mSv/yr* for intake of radionuclide in water set by World Health Organization (WHO) [16] as presented in Figure 4. These low values of annual effective doses show that most of the water samples from the study area could not be a threat on the health of the inhabitants of the area if taken directly since the water is properly treated.

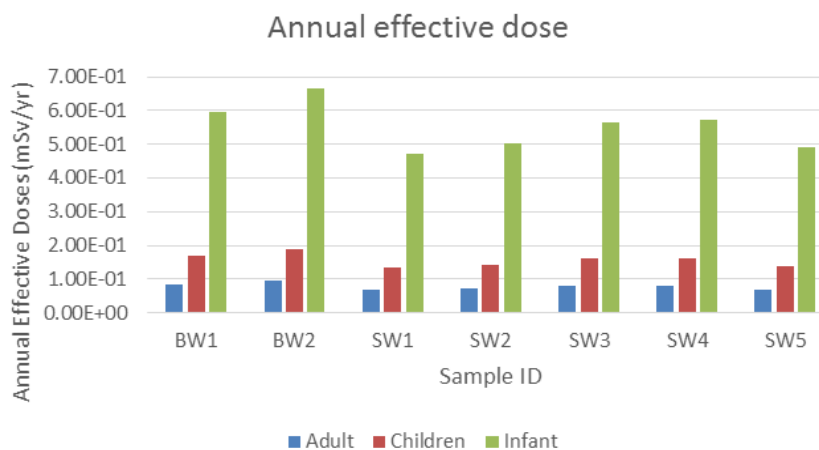


Figure-4. Bar graph of the annual effective doses for all water samples.

### 3.5. Mean Annual Effective Dose

The mean Annual Effective Doses due to ingestion of radon-222 from the two (2) water types were calculated for the three (3) categories of people and found to be 0.090, 0.181 and 0.632 *mSv/yr* in borehole water for adults, children and infants respectively. While mean annual effective doses due to ingestion of radon-222 in surface water

samples were found to be 0.074, 0.149, and 0.520 *mSv/yr* for adults, children and infants respectively. Most of the mean annual effective doses were found to be below World Health Organization recommended reference level of 0.1 *mSv/yr* for ingestion of radionuclide in water [16]. These results revealed that infants, for the same water consumption rate receive significantly higher doses hence have higher risk to cancer compared to children and adults as illustrated in Figure 5 with higher values of the mean annual effective doses for the three (3) categories of people coming from borehole water type.

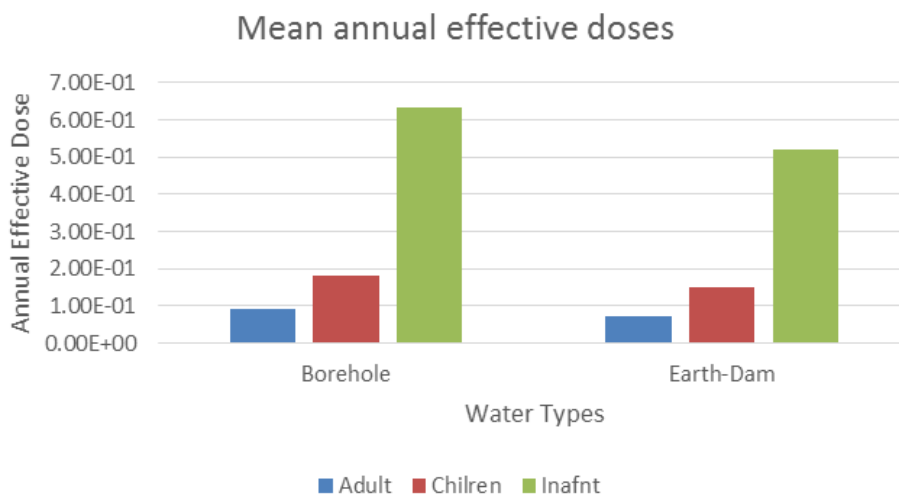


Figure-5. Bar graph of mean annual effective doses for the two water types.

### 3.6. Correlation between Radon-222 Concentration and the Elevation

In correlating between radon-222 concentration and the Elevation we find out that, it has an insignificant value of -0.3. That is to say the elevation does not play any role in either higher or lower concentration level of radon-222.

## 4. CONCLUSION

Results obtained from the measurement of the activity concentrations of radon-222 in water samples collected at different locations of sachet water companies in Dutsin-Ma LGA of Katsina state revealed that 86.67% of the recorded values of radon concentrations in the present study as well as the mean value obtained for the surface water type were below the world average Maximum Contamination Level (MCL) of 10 *Bq/L* set by World Health Organization and the MCL of 11.1 *Bq/L* set by United States Environmental Protection Agency [17] while the borehole water type was found to be above the average contaminated level. 100% of the recorded values of radon concentration which include both the Earth-Dam and borehole water samples are below the recommended action level of 100 *Bq/L* set by the World Health Organization (WHO) [18]. These significantly low values of radon concentration can be ascribed to the treatment and filtration given to the water for groundwater source by the water companies while that in the surface water (Earth-Dam) could be linked to the facts that, is exposed to the air and since radon is a gas it tends to escape into the air. Therefore, these water sources do not pose a threat to the health of the inhabitants of Dutsin-Ma LGA, Katsina state if continually ingested with proper treatment. The likelihood of this threat to health (which could be stomach or lung cancer) is more on infants and children than adults as



evident from the estimated Annual Effective doses of the corresponding radon concentrations in water in which most of the estimated annual effective doses were found to be below the reference level of 0.1 *mSv/yr* set by World Health Organization (WHO) [16] for intake of radionuclide in water.

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