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ORIGINAL RESEARCH ARTICLE

Initial Evaluation of Exposure of Adult Residents in Dange-Shuni Local Government Area to Radioactive Cesium (Cs-137) through Ingestion

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ABSTRACT

Radioactive Cesium (137-Cs) is widely used in hospitals as a gamma source for calibrating medical radiotherapy devices used in cancer treatment. It is also employed to calibrate radiation detection instruments. However, radioactive cesium-137 is one of the most concerning contaminants in water, as it emits both gamma and beta radiation, has a physical half-life of approximately 30 years, and a biological half-life of about 70 days. This work, therefore, aimed at assessing the radioactivity concentration of Cs-137 in the groundwater of the whole Dange-Shuni Local Government Area (LGA) using a High purity germanium (HPGe) detector. This will assist in confirming the annual effective dose and, thus, the lifetime cancer risk that Cs-137 can impose on the inhabitants of this environment. Stratified Random Sampling was used in sampling the water for the analysis to ensure adequate representation of possible different geological structures that exist in the study area. The activity concentration of Cs-137 was within the range of 4.65 ± 0.24 $Bq.L^{-1}$ to 96.42 ± 4.95 $Bq.L^{-1}$, with an average value of 13.72 BqL^{-1}. The activity concentration was found to be higher at Majia, whereas the lowest value was reported at Kalausar dutsi. The annual effective dose was estimated to be from 2.41 to 49.90 $mSvy^{-1}$ with a mean value of 7.09 $mSvy^{-1}$. With 2.17 x 10^{-3}, Majia had the greatest risk cancer mortality rating, while Kalausar Dutsi had the lowest, at 1.05 x 10^{-4}. Also, morbidity risk was found to be highest at Majia with a value of 3.15 x 10^{-3} and lowest at Kalausar Dutsi with a value of 1.52 x 10^{-4}. The notably high activity level observed in this study suggests that fractures in the granitic layers of the subsurface geology may have formed, leading to the extensive distribution of radiation doses in the area. Water softeners in the form of ion exchange can be applied to reduce the percentage of radionuclides in the drinking water of this environment.

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INTRODUCTION

Water is a vital resource for human life and various purposes. The collection of water below the water table that occurs from cracks and porosity of rocks and soil is referred to as groundwater. The water table of a place is the ground level at which the air and water pressures are equal (Ahmed, 2024; Dinh Chau et al., 2011; Nguelem *et al.*, 2013). Both natural and human activities damage groundwater in various ways in addition to its natural chemical composition, which can lead to several health issues (Altıkulaç, 2022). In Nigeria, groundwater is the most advantageous source of potable water. This is because, in contrast to surface water, it is easier to treat and cleaner. This has led to the excavation of numerous wells and boreholes all over the place in order to have access to potable water, and this much occurred in rural areas (Maxwell et al., 2015). The major way through which radioactive materials are deposited in the human body is basically by consumption. NORMS are also in the air that human beings inhale (El-Gamal *et al.*, 2019; Tchokossa et al., 2011). Radioactive compounds found in groundwater

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systems change from one site to another and usually arise from rocks and minerals that come in contact with the water (Zakaria, 2017).

People who have been exposed to natural radionuclides such as uranium (U-238), thorium (Th-234), potassium (K-40), Cesium (Cs-137), and others over an extended period of time may suffer devastation from radioactivity (Adekunle *et al.,* 2013). Cesium-137, as a progeny of nuclear fission reaction, is found in trace amounts from spontaneous disintegration of U-238 in the ground. Radioactive Cesium has a half-life of about 30 years and emits energetic beta and gamma radiation. This made it to be among the most worrisome radioactive contaminants in water (Koizumi et al. 2021). Therefore, exposure to radioactive Cesium has a great risk of internal exposure that can negatively affect cells in the human body. In cases of very high exposure, acute radiation effects such as nausea, vomiting, diarrhea, bleeding and coma can be experienced and even be fatal. The risk of cancer can also be increased due to exposure to Cs-137 because of its high-energy gamma radiation emission (Hannan et al., 2015).

In order to determine the radioactive threats to an environment's residents, the concentration of natural radioactivity in groundwater has been extensively studied worldwide (Benedik *et al.,* 2012; Saidu et al., 2012; Babakutigi et al., 2012; Saidu and Ike, 2013, Saidu and Bala 2018, Maxwell et al., 2015, Isah et al. 2022). While cesium-137 contamination has been linked to nuclear activities and natural processes, its presence in groundwater remains underexplored in Nigeria, particularly in regions like Dange-Shuni. This study addresses the lack of data on Cs-137 contamination in groundwater and its health implications for residents

MATERIALS AND METHOD

The Study Area

Dange-Shuni is a Local Government Area in Sokoto State, Nigeria. According to the 2006 census, the population of Dange-Shuni L.G.A. was 0.19 million, with a projected increase to 0.26 million by 2016, accounting for 0.44% of the total population of Sokoto State. The density of the L.G.A. population is 232 persons per km^2 with 1,126 km^2

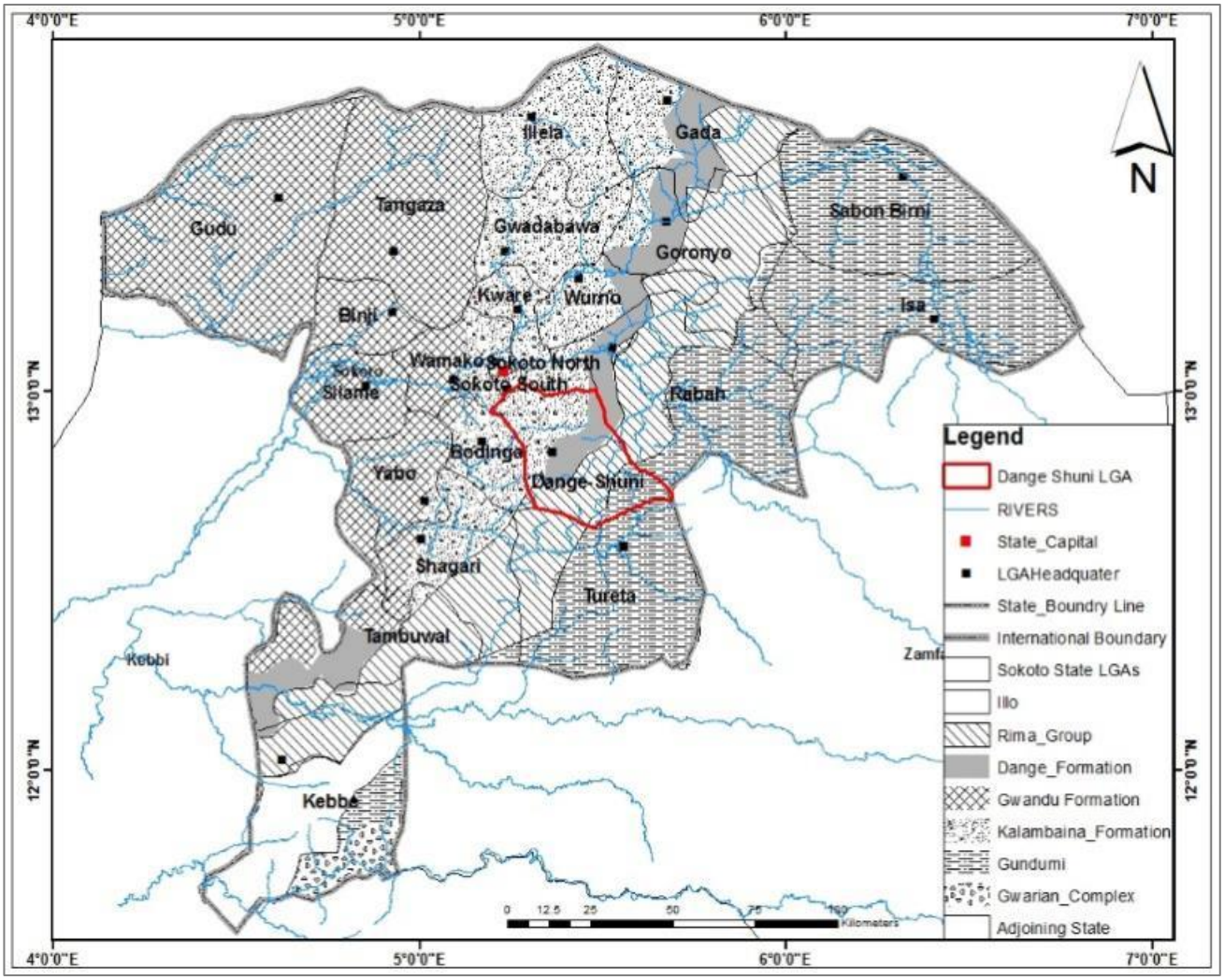

Figure 1: Extracted Map of the study area from the map of Sokoto State

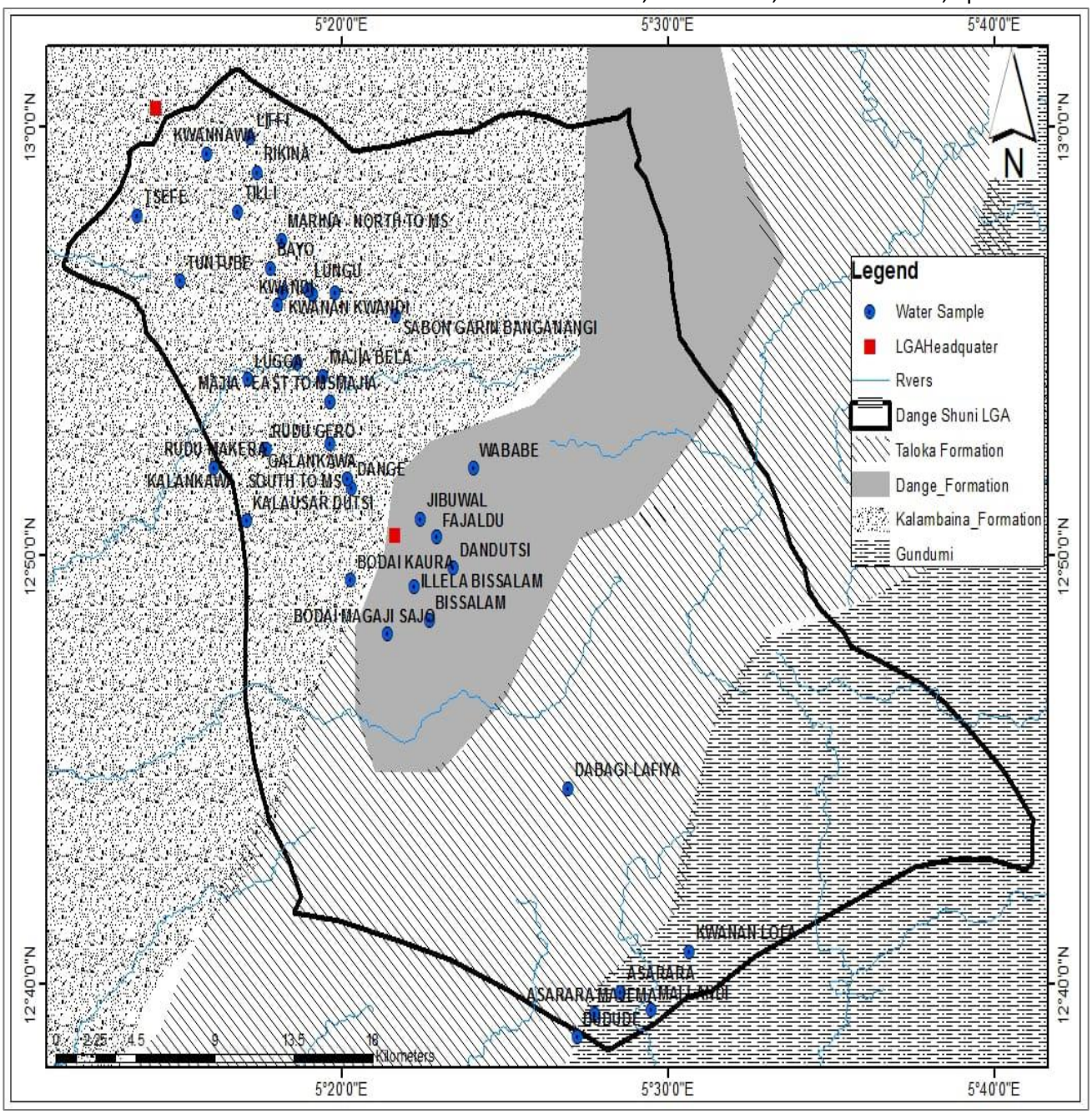

Figure 2: Map Showing some Sample locations in Dange-Shuni L.G.A

area. The area is within the geographical coordinates of Latitude, 12°39'00" N, 13°0'00"N and Longitude, 5°10'00" E, 5°40'02"E. The climate of the study area reflects the typical conditions of Sokoto State, with predominantly hot and dry weather throughout the majority of the year. The weather averages for the month of February; temperature averages around 37°C, and at night it feels like 19°C. The study area is shown in Figure 1. The figure displayed the map of Sokoto State from which the study area (Dange-Shuni) was extracted.

Sampling Technique

Stratified random sampling was employed as the sampling tool in this work. The stratified random sampling method ensured representative coverage of geological variations across the study area. In this study, the area was divided into 45 grids, each measuring 5.3 km by 5.3 km, resulting in an approximate area of 28.09 square kilometers per grid. A settlement was randomly selected from each grid using a simple random sampling method. Settlements in some grids are not accessible due to prevailing insecurity in that area. A total number of forty-three samples were collected, one sample from each grid. Figure 2 shows the position of some locations from where the samples were collected.

Sample Collection and Preparation

Forty-three samples of water from boreholes and wells in the study area were collected using a stratified random sampling method. Precautions were taken to avoid contamination, such as allowing the borehole water to flow for 5 minutes before sampling and using a filter for

hand-dug well samples. A polyethene container (1 litre) was used for the collection of samples. One percent of the space of the container was left unfilled for expansion. Dilute Nitric acid (15 ml) was added to prevent the walls of the container from absorption of radionuclides. The coordinates and elevations of the sample locations were recorded using Geographical Positioning System (GPS). The water samples were then taken to the Nuclear Research Centre Laboratory at the University of Ibadan for preparation and analysis. With the aim of enabling the water samples to reach secular equilibrium prior to the counting process, they were left at the preparation laboratory for twenty-eight days.

Sample Analysis

The concentration measurement of radionuclides in all samples was conducted using a Camberre P-type High Purity Germanium (HpGe) detector, measuring 69.8 mm in length and 78 mm in diameter, with a relative efficiency of 80%. The detector was made in Germany by ORTEC. The detector was housed within a 10 cm thick lead shield to minimize interference from background radiation in the surroundings and liquid nitrogen was used for cooling purposes. The entire electronic system was linked to a PC-based multichannel analyzer for gamma spectrum analysis. The HPGe detector was calibrated for energy and efficiency using the 1.33 MeV gamma line of 60Co^{60}\text{Co}60Co, achieving an energy resolution of 2.3 keV (FWHM) with a relative yield of 1.73%. A 500 mL Marinelli beaker was employed to ensure consistent geometry for both the standard source and the samples. An amplifier was incorporated into an analog-to-digital converter (ADC) to process signals from the HPGe detector.

Minimum Detectable Activity

This concept is crucial for determining the activity of a specific sample. The minimum detectable activity represents the lowest level of radioactivity that can be identified under specific conditions. The minimum detectable activities for the radionuclides of interest were calculated using the average peak areas of the gamma-ray lines, as outlined in Equation (1).

$$M.D.A = \frac{\sigma\sqrt{B}}{\eta PTW} \quad (1)$$

Here, σ represents the statistical coverage factor with a value of 1.645 (corresponding to a 95% confidence level), B denotes the background count in the region of interest for each radionuclide, P is the gamma emission probability (gamma yield) for each radionuclide, T is the counting time in seconds, W is the weight of the sample container, and η represents the detector efficiency at the measured gamma-ray energy.

Radionuclides Activity Concentration

The activity concentration of 137-Cs was calculated using the 661.7 keV gamma peaks, as described in Equation (2).

$$A_C = \frac{C_N}{P_\gamma ME} \quad (2)$$

Here, AC represents the activity concentration of the radionuclide in the sample (in Bq/L), Cn is the net count under the corresponding peak, Pγ is the absolute transition probability of the specific gamma ray, M is the mass of the water sample, and E is the detector efficiency at the specified gamma-ray energy.

Estimation of Annual Committed Effective Dose from Drinking Water

The radioactivity was converted into effective doses using an ingestion dose coefficient of 0.013 μSv/Bq for ^{137}Cs. (ICRP, 1996).

$$\text{AED } (\mu Svy^{-1}) = \text{AC } (BqL^{-1}) \times \text{DC } (\mu SvBq^{-1}) \times \text{AWC } (L\ y^{-1}) \quad (3)$$

Where AED is the annual effective dose (μSvy^{-1}), AC is the activity concentration of the radionuclide ($Bq.L^{-1}$), DC is the dose coefficient for ^{137}Cs in ($\mu Sv.Bq^{-1}$), and AWC is the annual water consumption in liters per year.

Cancer risk assessment from consumption of water

The lifetime cancer risks (R) related to the ingestion of a certain radionuclide were calculated using equation (4) (Maxwell et al., 2015).

$$R = r \times I \quad (4)$$

Where R is the lifetime cancer risks related to the consumption of Cesium in water, r is the cancer risk coefficient, and I is the per capita activity intake. The per capita activity intake (I) was estimated by multiplying the activity concentration in Bq/L by the total lifetime water intake. As regulated by the World Health Organization (WHO), the average life expectancy in Nigeria is 54.5 years, with an annual water consumption of approximately 730 liters per adult, which lead to a calculated lifetime water intake of 39,785 liters. The cancer mortality and morbidity risks for an adult were considered. The evaluation of the lifetime cancer mortality risk was done using cancer risk coefficients adopted from the "EPA Federal Guidance Report 13". The cancer risk coefficient (r) of 137-Cs is 5.66 x 10^{-10} Bq^{-1} for mortality and 8.22 x 10^{-10} Bq^{-1} for morbidity (USEPA, 1999).

RESULTS AND DISCUSSION

The average activity concentration of Cs-137 in the groundwater system of the area was determined, and the annual effective dose, which is expected to be less than the world standard, was calculated using the dose conversion factor taken from "ICRP Publication 72,". The cancer risk was evaluated considering the cancer risk coefficient adopted from "EPA Federal Guidance Report 13." This will enable decision-makers as well as consumers to know the level of their safety with respect to the water being used. The activity concentrations ($Bq.L^{-1}$) of Cs-137 and its metastable daughter nuclide ^{m}Ba-137 from the study area were displayed in Table 1.

Table 1: Activity concentration of Cs-137 and ^{m}Ba-137

S/N	Location	Latitude	Longitude	Activity Bq/L	
				Cs-137	^{m}Ba-137
1	Dabagi-lafiya	12.74263	5.44903	31.25	29.38
2	Bissalam	12.80788	5.37806	40.09	37.68
3	Bodai magaji sajo	12.80245	5.35648	0.00	0.00
4	Bodai kaura	12.82361	5.33800	11.67	10.97
5	Illela bissalam	12.82077	5.37061	21.92	20.60
6	Fajaldu	12.84044	5.38187	16.06	15.10
7	Wababe	12.86704	5.40073	34.53	32.46
8	Dandutsi	12.82816	5.39042	20.30	19.08
9	Jibuwal	12.84747	5.37360	6.72	6.32
10	Kalausar dutsi	12.84668	5.28475	4.65	4.37
11	Rudun makera	12.86730	5.26810	16.91	15.90
12	Rudun gero	12.87443	5.2949	0.00	0.00
13	Amanawa	12.90819	5.31074	0.00	0.00
14	Dange	12.85942	5.33827	0.00	0.00
15	Galankawa	12.86272	5.33617	10.62	9.98
16	Majia	12.89285	5.32738	96.42	90.63
17	Majia bela	12.90287	5.32383	26.83	25.22
18	Kwandi	12.93034	5.30072	0.00	0.00
19	Lugga	12.90172	5.28567	0.00	0.00
20	Kwanan kwandi	12.93548	5.30317	0.00	0.00
21	Lungu	12.93643	5.31613	0.00	0.00
22	Sabon garin banganangi	12.92643	5.36102	21.16	19.89
23	Bayo	12.94475	5.29723	0.00	0.00
24	Tuntube	12.93979	5.25102	0.00	0.00
25	Tsefe	12.96524	5.22870	18.95	17.81
26	Asarara	12.66346	5.47557	0.00	0.00
27	Budude	12.64593	5.45373	0.00	0.00
28	Asarara majema	12.65511	5.46268	0.00	0.00
29	Kwanan lofa	12.67919	5.51107	0.00	0.00
30	Mallandi	12.65648	5.49167	30.36	28.54
31	Tilli	12.96677	5.28046	0.00	0.00
32	Rikina	12.98210	5.29028	36.64	34.44
33	Liffi	12.99556	5.28665	15.03	14.13
34	kwannawa	12.98940	5.26428	0.00	0.00
35	Kalankawa	12.87272	5.33558	0.00	0.00
36	Kalankawa - South	12.86809	5.33965	0.00	0.00
37	Gidan gara – North	12.87810	5.32687	21.71	20.41
38	Majia-East	12.89273	5.32710	52.36	49.22
39	Lungu	12.93754	5.31933	0.00	0.00
40	Marina - North	12.95286	5.30317	6.15	5.78
41	Lungu - South	12.93473	5.31825	0.00	0.00
42	Makera – East	12.93459	5.33003	9.43	8.86
43	Lungu – West	12.93650	5.31671	40.09	37.68
			Minumun	**4.65**	**4.37**
			Maximum	**96.42**	**90.63**
			Average	**13.72**	**12.89**

Figure 3 shows the activity concentration of Cs-137 in the groundwater system of the study area. The activity of Cesium was found to be non-detectable at some locations. Where it was detected, it ranged from 4.65 ± 0.24 to 96.42 ± 4.95 Bq.L^{-1}, with an average value of 13.72 BqL^{-1}. The activity concentration of Cs-137 was detected to be highest at Majia with the value of 96.42 ± 4.95 Bq.L^{-1}, whereas its lowest value of 4.65 ± 0.24 Bq.L^{-1} was reported at Kalausar dutsi. Table 1 shows that, with regard to the adopted guidance level (GL) of 10 Bq.L-1 (WHO, 2006) for Cesium in drinking water, the activity concentration of Cs-137 is higher in some settlements than in others. This is most likely because of differences in the depth of wells and boreholes as well as in the geology of the subsurface rocks. According to Obaje et al. (2013), the study area is separated into three geological formations: the Dange formation, which consists primarily of shales separated by the calcareous; the Kalambaina formation, which consists of limestones and is very rich in carbonate; and the Rima group, which

consists of mudstones and friable sandstones separated by the fossiliferous, calcareous, and shaley. Differences in the geological formations may also be the cause of the variations in the activity concentrations.

Cs-137 is known to be a good beta–gamma emitter with energies of 0.51 MeV (92 %) and 1.17 MeV (8 %). The decaying product is metastable ^{m}Ba-137, which emits a gamma photon of energy 0.661 MeV. The decaying product of ^{m}Ba-137 is stabile Ba-137. The daughter ^{m}Ba-137 is in secular equilibrium with its parent Cs-137. The main contribution of 137-Cs to risk from the radiations emitted by the ^{m}Ba-137. The activity concentration of 137Cs is multiplied by 0.94 to get the activity concentration of ^{m}Ba-137, which is in a secular equilibrium with parent ^{137}Cs. (USEPA, 1999). In Table 1, the activity concentration of ^{m}Ba-137 was shown with maximum and minimum values of 90.63 Bq/L and 4.37 Bq/L at the Majia and Kalausar dutsi locations, respectively. Not a great difference exists between the activity concentration of the mother and daughter radionuclides.

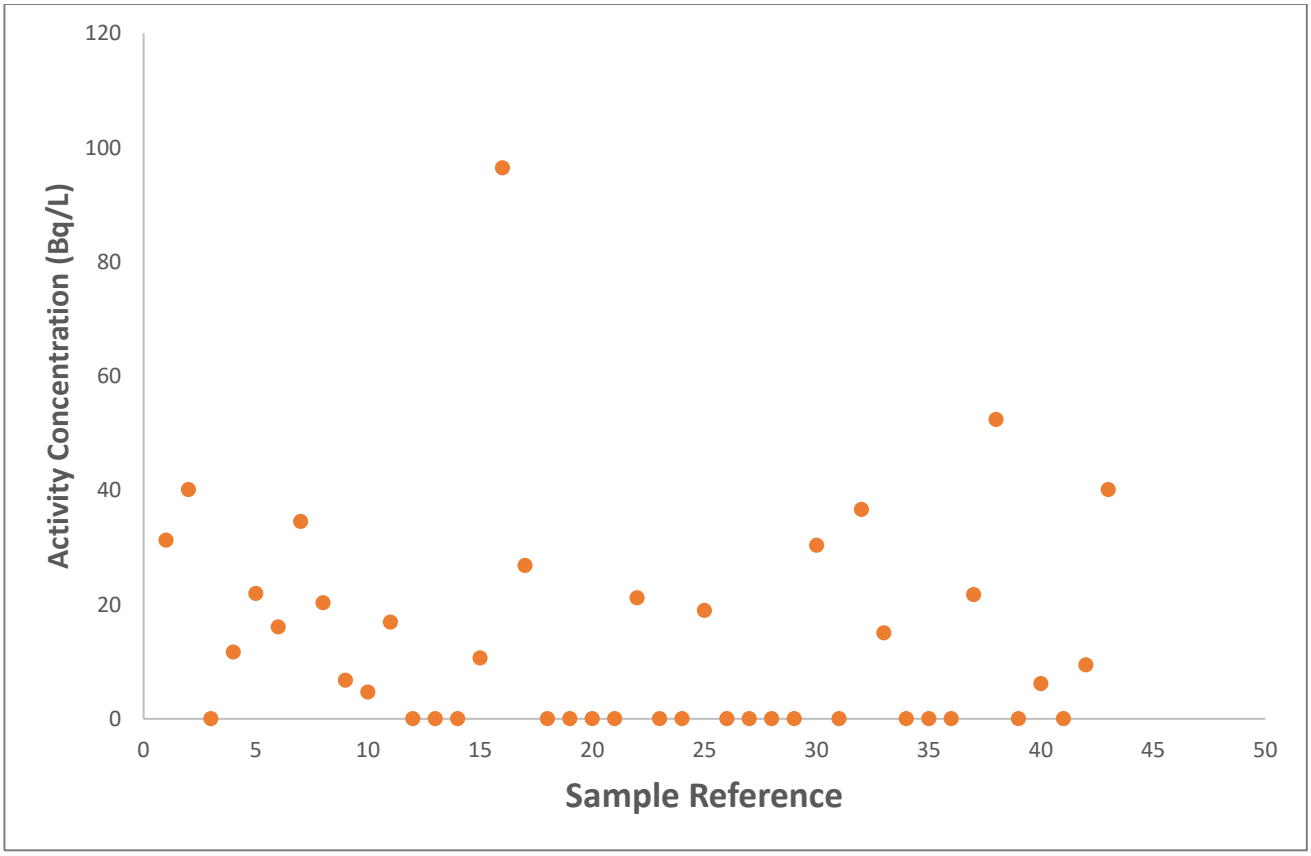

Figure 3: Distribution of radionuclide ^{137}Cs

Figure 3 illustrates the variability in Cs-137 activity across the study area, with the greater values recorded at Majia, likely due to geological fractures. This inhomogeneous distribution was due to differences in the geological structures in the locations from where the groundwater was collected. In this work, the activity concentration of Cesium greatly exceeded the screening limit of 10 Bq/L at most of the locations (where the nuclide was detected). This could be due to the mining exercise happening in the neighboring state of Zamfara State. Furthermore, it is a blatant sign of potential radioactive percolation from rocks into the local groundwater.

The activity concentration in Bq L-1, the dose conversion factor of the radionuclides supplied in Sv.Bq-1, and the typical adult's annual water consumption rate in liters were all taken into consideration when calculating the annual effective dose resulting from the ingestion of Cs-137. Table 1 previously showed the radionuclides' activity concentration. The annual effective dosage that an individual would receive from consuming natural radionuclide Cs-137 from all of the water samples in the research area was determined using Equation 3, and the results were displayed in Table 2.

The annual effective dose due to consumption of Cs-137 was displayed in Figure 2 above. It can be seen there in excessive values of AED. This is the consequence of the high activity concentration of the radionuclide Cs-137. The majority of regions with higher Cs-137 values are associated with samples from boreholes, which are deeper than hand-dug wells. The average estimated dose level in $mSvy^{-1}$ was 7.09 $mSvy^{-1}$, ranging from not detectable to 49.90 $mSvy^{-1}$. The Annual effective dose due to the consumption of radioactive Cesium by the population of Fukushuma prefecture of Japan was within the average of 3.0 μSvy^{-1} to a maximum of 83.1 μSvy^{-1} (Koizumi et al., 2012). The effective dose due to ingestion is lower at Fukushuma than in the present study. Although there was

nuclear fallout at Fukushuma, the concentration of nuclide Cs-137 is much higher in the study area.

Radiological assessment of different radionuclides (^{238}U, ^{234}Th and ^{40}K) in groundwater of the present study area (Dange-Shuni LGA) and some parts of Sokoto state (Wurno LGA) was made, and the cumulative annual effective dose from those nuclides was assessed (4.19×10^{-4} $mSv.y^{-1}$ and 0.32 $mSv.y^{-1}$ at Dnge-Shuni and Wurno respectively). The AED due to Cesium is higher than due to those nuclides (Wasagu, 2024; Isah et al. 2022). This is because the cesium activity concentration found in the area is also higher than that of those radioisotopes.

Table 2: Annual Effective Dose and Cancer Risk Indices

S/N	Location	AED ($mSvy^{-1}$)	Mortality	Morbidity
1	Dabagi-lafiya	16.20	7.04E-04	1.02E-03
2	Bissalam	20.70	9.03E-04	1.31E-03
3	Bodai magaji sajo	0.00	0.00E+00	0.00E+00
4	Bodai Kaura	6.04	2.63E-04	3.82E-04
5	Illela bissalam	11.30	4.94E-04	7.17E-04
6	Fajaldu	8.31	3.62E-04	5.25E-04
7	Wababe	17.90	7.78E-04	1.13E-03
8	Dandutsi	10.50	4.57E-04	6.64E-04
9	Jibuwal	3.48	1.51E-04	2.20E-04
10	Kalausar dutsi	2.41	1.05E-04	1.52E-04
11	Rudun makera	8.75	3.81E-04	5.53E-04
12	Rudun gero	0.00	0.00E+00	0.00E+00
13	Amanawa	0.00	0.00E+00	0.00E+00
14	Dange	0.00	0.00E+00	0.00E+00
15	Galankawa	5.49	2.39E-04	3.47E-04
16	Majia	49.90	2.17E-03	3.15E-03
17	Majia bela	13.90	6.04E-04	8.77E-04
18	Kwandi	0.00	0.00E+00	0.00E+00
19	Lugga	0.00	0.00E+00	0.00E+00
20	Kwanan kwandi	0.00	0.00E+00	0.00E+00
21	Lungu	0.00	0.00E+00	0.00E+00
22	S/gari banganangi	10.90	4.76E-04	6.92E-04
23	Bayo	0.00	0.00E+00	0.00E+00
24	Tuntube	0.00	0.00E+00	0.00E+00
25	Tsefe	9.80	4.27E-04	6.20E-04
26	Asarara	0.00	0.00E+00	0.00E+00
27	Budude	0.00	0.00E+00	0.00E+00
28	Asarara majema	0.00	0.00E+00	0.00E+00
29	Kwanan lofa	0.00	0.00E+00	0.00E+00
30	Mallandi	15.70	6.84E-04	9.93E-04
31	Tilli	0.00	0.00E+00	0.00E+00
32	Rikina	19.00	8.25E-04	1.20E-03
33	Liffi	7.77	3.38E-04	4.92E-04
34	kwannawa	0.00	0.00E+00	0.00E+00
35	Kalankawa	0.00	0.00E+00	0.00E+00
36	Kalankawa -South	0.00	0.00E+00	0.00E+00
37	Gidan gara –North	11.20	4.89E-04	7.10E-04
38	Majia-East	27.10	1.18E-03	1.71E-03
39	Lungu	0.00	0.00E+00	0.00E+00
40	Marina - North	3.18	1.38E-04	2.01E-04
41	Lungu - South	0.00	0.00E+00	0.00E+00
42	Makera – East	4.88	2.12E-04	3.08E-04
43	Lungu – West	20.70	9.03E-04	1.31E-03
	Min	**2.41**	**1.05E-04**	**1.52E-04**
	Max	**49.90**	**2.17E-03**	**3.15E-03**
	Average	**7.09**	**3.09E-04**	**4.49E-04**

The major purpose of every radiological risk assessment is to determine the lifetime cancer risk due to the consumption of radionuclides. According to equation 4, the lifetime cancer risks (R) linked to consuming a specific radionuclide (Cs-137) were calculated by multiplying the relevant risk coefficient (r) by the per capita activity intake (I). Activity concentration in Bq.L-1 multiplied by lifetime water intake yields the per capita activity intake (I). Only

adult-age cancer mortality and morbidity risks were taken into account. The World Health Organization suggested Nigeria's average life expectancy to be 54.5 years, while the average adult's yearly water consumption is approximately 730 L year-1 (WHO, 2006). This adds up to an estimated lifetime water intake of 39,785 L.

The major purpose of every radiological risk assessment is to determine the lifetime cancer risk due to the consumption of radionuclides. According to equation 4, the lifetime cancer risks (R) linked to consuming a specific radionuclide (Cs-137) were calculated by multiplying the relevant risk coefficient (r) by the per capita activity intake (I). Activity concentration in Bq.L-1 multiplied by lifetime water intake yields the per capita activity intake (I). Only adult-age cancer mortality and morbidity risks were taken into account. The World Health Organization suggested Nigeria's average life expectancy to be 54.5 years, while the average adult's yearly water consumption is approximately 730 L year-1 (WHO, 2006). This adds up to an estimated lifetime water intake of 39,785 L.

Cancer risk coefficients (r) of ^{137}Cs is 5.6 x 10^{-10} Bq^{-1} for mortality and 8.22 x 10^{-10} Bq^{-1} for morbidity (USEPA, 1999). The results for the mortality and morbidity are shown in Table 2. From there (Table 2), it can be seen that cancer mortality risk due to ^{137}Cs has an average value of 3.09 x $10^{-4,}$ ranging from non-detectable to 2.17 x 10^{-3}, while cancer morbidity risk also falls within the range of none detectable to 3.15 x 10^{-3} and average value of 4.49 x 10^{-4}. The highest mortality and morbidity values were found in Majia.

In contrast with the study reported by Wurno Local Government Area, which shares a common geological formation with the present study, the mean cancer mortality value due to ingestion of uranium nuclide was 1.02 × 10^{-4} (Isah et al. 2022). This is 3 times lower than the mortality average value reported in this work. In contrast, the cancer morbidity risk obtained in this study is greater than the one obtained in the groundwater of Wurno, a factor of about 4.

The changes in the geological formations, depth to sedimentary thickness, and activities occurring in the locations may be the cause of the variation in the cancer mortality and morbidity values found in this study and some of the previously stated studies. According to theory, sedimentary thickness identifies the many rock types that can be found in a subterranean geology and, consequently, the components that may be present at high or low radiation doses (USEPA, 1999). Since the subsurface geology permits the rapid downward transfer of water sources from the source, mining activity surrounding the study area and tectonic activity of deformed fractures that allow water to trap at the near-surface may be the main causes of the high radiation dose that raises cancer mortality and morbidity rates.

CONCLUSION

Determining whether there is a higher danger area for residents, whether there is a higher risk in consuming food and water, and the effects of man-made terrestrial radiation are all crucial aspects of environmental radiation protection. Because of mining activities in Zamfara State and its neighboring settlements in Sokoto State, monitoring radioactivity in soil and water became recommendable. The chance of developing cancer was found to be very low despite the high doses from internal exposure to ^{137}Cs radionuclides found in the study area's groundwater. The creation of risk assessment techniques is crucial since the overall impact of radiation should be the basis for nuclear management decision-making. Therefore, our study emphasizes how urgently routine groundwater monitoring and public health initiatives are needed to reduce radiological risks in Dange-Shuni.

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