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Gross Alpha and Gross Beta Activity Concentrations and Annual Effective Dose due to Intake of water from the Cement Producing Area of Sokoto, North-western Nigeria.

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Abstract

Mineral radioactivity is due to alpha, beta and gamma radiation from the unstable isotope in the composition. Gross alpha and beta activity concentration in ground water from cement producing area of Sokoto State has been determined using a non-gas proportional counter with model, protean instrument corporation (PIC) MPC 2000 DP single channel analyzer of Centre for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria. The mean activity concentration of gross alpha and beta were 0.05 and 0.14 BqL^{-1} respectively. These values were compared with the reported data from other studies and they were well within the World Health Organization (WHO) recommended limits of 0.1 and 1.0 BqL^{-1} for activity concentration of gross alpha and beta respectively. The mean annual effective dose due to activity concentration of both gross alpha and beta from intake of drinking water for children and adults were calculated to be 0.225 and 0.06 $mSvy^{-1}$. This is in order to estimate the exposure risk arising from intake of water. This value is below the recommended reference dose level (RDL) of the effective dose of 0.1 $mSvy^{-1}$. This study has shown that ground water from the communities around the cement producing area of Sokoto has slight contaminated radiologically, which might pose radiation related health risk to the public in the future.

Keywords: Activity concentration of gross alpha, beta, effective dose, proportional counter, Sokoto.

INTRODUCTION

Drinking water, especially from ground sources have varying range of chemical quality. The quality depends on the mineralogy, surrounding anthropogenic and also the degree of equilibrium that has been achieved between water and rock (Fassae *et al.*, 2015). Water resources are contaminated by primordial radioactive isotopes of ^{238}U, ^{232}Th and ^{40}K. Human activities such as that of cement production that include mining, milling, processing and burning of fossil fuels (coal) have raised the concentrations of naturally occurring radioactive materials in the environment (Ogundare and Adekoya, 2015).

High levels of radionuclide in the soil as well as ground water are associated with low-grade radionuclides deposits. Water contains a number of both alpha emitters (such as ^{238}U, ^{226}Ra, and ^{210}Po) and beta emitters (such as ^{40}K, ^{228}Ra and ^{210}Pb). These enter the human body basically through food and water ingestion. The presence of them in water poses a number of health problems especially when these radionuclides are deposited in the human body through drinking water. Dissolved radionuclide in body emits particles (alpha and beta) and

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photons (gamma) which gradually interacts with living tissues (Gruber *et al*., 2009; Ogundare and Adekoya, 2015).

It has been part of World Health Organization (WHO) guidelines for screening drinking water to perform an indirect evaluation of effective dose by measuring gross alpha and gross beta radioactivity in drinking water and checking the level of compliance to reference dose level of 0.1 and 1.0 $\mathrm{BqL^{-1}}$ for gross alpha and gross beta activity respectively (WHO, 2004). The values of gross alpha radioactivity originating from these alpha emitters in ground water samples depends on the geological characteristics of the area, content of mineral deposits and the type of human activities in the area. In environmental monitoring, much attention has been given to gamma emitter's detection and quantification even where it is possible to have alpha and beta emitters (Lu *et al*., 2012; Mehade *et al*., 2014). Despite gamma rays have relatively high penetrating power when compared to alpha and beta particles, effect of alpha and beta particles inside the body are by far more detrimental to human health.

Available literature reveals that the geology of Sokoto cement processing area and its environs contains significant amount of limestone, sand stone and siltstones deposits within the phosphate sedimentary geology of the area (Albert *et al*., 2016; Obaje, 2009). High rate of cement production in Sokoto cement plant, increases the exploiting rate of Kalambaina limestone deposit through mining, there is need to assess the environmental impact of mining on the environment. This includes the assessment of gross alpha and beta activities in ground water as well as the effective dose to the inhabitants of the area. Available literature on ground water quality in terms of gross alpha and beta radioactivity was the survey of gross alpha radioactivity in bore hole and well water in Sokoto city (Saidu and Ike, 2013). Therefore, the aim of this study is to evaluate the gross alpha and gross beta radioactivity in ground water from cement producing area of Sokoto and also determine effective dose of the general public. The result could stand as a radiological baseline data for the area.

MATERIALS AND METHODS

Location of the study area.

The study area was the environs of the cement industrial area of Sokoto, Northwestern Nigeria. It is the only cement production plant in Northwestern Nigeria. The study area falls under Sokoto Basin which is the southern extension of the lullemmeden Basin, Figure 1. Marking of Kalambaina area as the location for siting the cement company was to take advantage of proximity to the large deposit of limestone (thus, the principal ingredient for the cement production) in the area. The lullemmeden Basin is entirely a cratonic basin created by tectonic epirogenic movements or stretching and rifting of tectonically stabilized crust during the Palaeozoic (Yelwa *et al*., 2015).

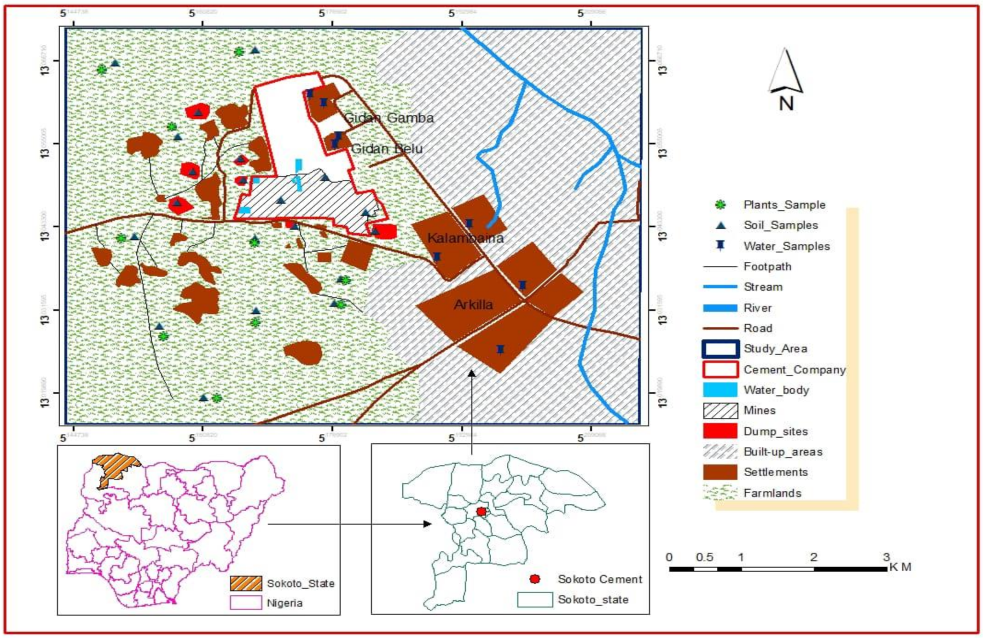

Figure 1: Map of the study area.

The rainy season is usually from June to October. From late October to February, during the 'cold season', the climate is dominated by the harmattan wind blowing Sahara dust over the land. The rock type around Sokoto cement company is majorly phosphate rock which is primarily associated with the Sokoto Group of sediment comprising of shale, limestone and phosphate pellets. The study area is characterized majorly with bared land and sparse vegetation. The climate is that of semi-arid with an annual temperature range of 28.3 °C (82.9 °F) to 45 °C (113.0 °F). The warmest months are February to April, where daytime temperatures can exceed (Albert *et al*., 2016; Obaje, 2009).

Sample Collection

For the purpose of this study, the study area was divided into five zones, based on the communities around and their water sources. These zones. include Gidan Gamba (GG), Gidan Belu (GB), Arkilla (AR), Kalambaina (KB), and Mines (MS) of the company. Water samples were collected from available ground water sources in the study area. The ground water collected include boreholes, hand dug wells and seepages in the mines. Two samples were collected from each zone in the study area. The inhabitants of the area rely majorly on underground water resource available in the area including hand dug wells, boreholes and quarry seepages. Water samples were collected manually in the early hours of the day from community wells of varying depths, a borehole and mines seepages. Also, two samples were collected as control (CS) from a community with the sample geology, away from the company's influence. Each water sample was collected into the labeled two liters (2 L) plastic bottle. The bottles were first washed with clean water three times to minimize contamination, filled to the brim (water plus HNO_3 acid) without any head space and hermetically tight to prevent CO_2 from being trapped and dissolve in water which might affect the chemical content of water. Concentrated Trioxonitrate (V) acid HNO_3 of about 20 mL ± 0.1 mL per liter was immediately added to the water to maintain the integrity of the sample (Avwiri, 2005). Coordinates of all the sampling points were also captured using hand held GPS (Model:78s). All samples were transported to the Center for Energy Research and Training, Ahmadu Bello University Zaria (CERT) for preparation and analysis.

Sample preparation and analysis

The samples were prepared by adopting the standard procedures reported by (ISO, 1992, Avwiri *et al*., 2016, Avwiri, 2005 Mustapha, 2017., Bello *et al*., 2019). A liter from each of the collected water samples was evaporated at Center for Energy Research and Training, Ahmadu Bello University Zaria (CERT) using hotplates at an appropriate moderate heat in an open 600 mL beaker. The residues from the evaporation were kept in the desiccators until they were ready for counting. However, in the process of evaporation, whenever the level of sample in the beaker reached 50 mL, it was then transferred into a petri-dish and placed under infrared light source to accomplish drying the residue. It was then allowed to cool before weighing it. The weight of the residue was obtained by subtracting the weight of the empty petri-dish from the weight of petri-dish plus sample residue. An empty planchette was weighed after which about 0.077 g of the residue was transferred to the planchette. The planchette plus residue was then weighted. A few drops of Vinyl acetate were put on the sample to make them stick to the planchette to prevent scattering of the residue during counting. The Volume V, of sample that produced 0.077 g was calculated using Equation 1.

$$0.077\ \mathrm{g} \times \mathrm{V_T} = \mathrm{T_R V} \qquad 1$$

where, V_T is the volume that produce the total residue, T_R is the weight of the total residue and V is the volume that gave 0.077 g.

The volume of water that gave the total residue was obtained from Equation 2.

$$\mathrm{V} = \frac{\mathrm{V_T}}{\mathrm{T_R}} \times \mathrm{R_P} \qquad 2$$

where, V_T is the volume of water (1 L), T_R is the total residue obtained from V_T in mg and R_P is the residue transferred to Placket.

The sample preparation and sample efficiencies were obtained from Equation 3 and 4 respectively:

$$\text{Sample preparation efficiency} = \frac{\text{weight of residue}}{0.077\text{g}} \times 100\% \qquad 3$$

$$\text{Sample efficiency} = \frac{\mathrm{R_F}}{\mathrm{T_R}} \times 100\% \qquad 4$$

where R_P is the sample weight on the planchette in (mg) and T_R is the the total sample weight from evaporating 1000 mL of water sample in (mg).

Determination of gross alpha and gross beta radioactivity concentrations in water

A non-gas proportional counter with model, protean instrument corporation (PIC) MPC 2000DP single channel analyzer of Centre for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria was used for the gross alpha and gross beta radioactivity measurements via the standard procedures reported by (ISO, 1992., Bello *at al*., 2018). For this purpose, the prepared sample was placed in a 5cm diameter stainless steel planchette and later placed in a sample carrier which was then placed on the sample drawer and closed. For both gross alpha and gross beta measurements, a high voltage of 1650 V was used and samples were counted for 5 cycles of 2700 sec per cycle. The counting was done automatically according to the selected count mode (either α only, β only, or αβ mode) with the appropriate sample information (channel efficiency and background count rate, volume of sample used and sample efficiency) and the operating voltage set at 1650 V. The system was calibrated for α and β energies using Pu - 239 and Sr - 90 sources respectively. The detector has efficiencies and detection limits of 87.95 % and 0.21 cpm for alpha; and 42.06 % and 0.22 cpm for beta as specified by the manufacturers; while detector background count rates were 0.60 cpm for alpha and 0.70cpm for beta and was determined with measurement for length of time that routine samples were counted and using a clean, empty planchette in the detector. The alpha and beta activity concentration ($\mathrm{BqL^{-1}}$) were calculated using Equation 5.

$$\alpha, \beta \text{ radioactivity } \left(\frac{\mathrm{Bq}}{\mathrm{l}}\right) = \frac{\text{Rate }(\alpha,\beta) - \text{Bgd}(\alpha,\beta)}{\text{Sample efficiency X detector Efficiency X Sample Volume}} \quad 5$$

The effective dose to an individual (adult and children) over one year was calculated using Equations 6 and 7 respectively (IAEA, 2003).

$$E_{avg}\left(\frac{\alpha}{\beta}\right) = \sum A_{i\left(\frac{\alpha}{\beta}\right)} \times DCF_{i\left(\frac{\alpha}{\beta}\right)} \times 730 \ \text{(for Adult)} \quad 6$$

$$E_{avg}\left(\frac{\alpha}{\beta}\right) = \sum A_{i\left(\frac{\alpha}{\beta}\right)} \times DCF_{i\left(\frac{\alpha}{\beta}\right)} \times 183 \ \text{(for children)} \quad 7$$

where E_{avg} (α/β) is the average gross annual α or β committed effective dose in drinking water, $A_{i(\alpha/\beta)}$ is the gross α or β activity concentration of individual radionuclides present in water samples and $DCF_{i(\alpha/\beta)}$ is the dose conversion factor in $SvBq^{-1}$ for ingestion of the individual radionuclide. It was assumed that adult consume a minimum of 2 litres of water per day resulting in annual consumption rate of 730 litres per year while infant consumes half litre of water per a day (1/2 l/d) resulting in annual intake rate of 183 litres per year (EPA).

RESULTS AND DISCUSSIONS.

Gross alpha and gross beta activity concentrations in samples of various ground water samples for drinking in the communities around Sokoto cement company ware calculated using Equation 5. The gross alpha activity concentration ranged from 0.009±0.001 BqL^{-1} to 0.131±0.01 BqL^{-1} and not detected in the control sample, Table 1. The gross beta activity concentration ranges from 0.029±0.002 BqL^{-1} to 0.273 ± 0.02 BqL^{-1}, while the control samples recorded 0.010±0.008 BqL^{-1}, Table 1. There was no significant difference between the radioactivity of both alpha and beta in well and borehole water from the study area. This result is in agreement with the survey of gross alpha radioactivity in bore hole and well water in Sokoto city (Saidu and Ike, 2013). All obtained activities for both alpha and beta from this study were well within the WHO recommended limit of 0.1 and 1.0 BqL^{-1} respectively. Mean gross alpha and gross beta activity concentrations, for the samples from the study area, control sample as well as WHO recommended limit were compared in Figure 2.

The result of gross alpha activity from this study was lower than 0.01 BqL^{-1} to 6.00 BqL^{-1} from survey of gross alpha radioactivity in bore hole and well water in Sokoto city (Saidu and Ike, 2013). This indicates that activities of cement production in the area do not affect the ground water sources in the area in this direction. Meanwhile, the result of alpha activity of the present study was higher than 0.002871±0.00957 to 0.05335±0.0253 BqL^{-1} obtained from similar study around Obajana cement factory, Northcentral, Nigeria. However, beta activity was in the range of 0.2937±0.0588 to 39.96±11.3000 BqL^{-1} (Bello *et al.*, 2018), which was higher than the present study. In this study highest gross alpha and gross beta activity concentrations were recorded at Gidan Gamba, a location about 500 m from the mines of the company. Since water from seepages that were found within the mines recorded lower gross alpha and gross beta activity concentrations the results of Gidan Gamba might be due to rich loamy deposit in the area. Loamy soil generally contains more nutrients, moisture than clay or sandy soils. Similar observation was made in study on the gross alpha and gross beta activities in water of solid minerals processing areas of Enugu state South- East Nigeria (Avwiri *et. al.*, 2016). The least gross alpha and gross beta activity concentration was recorded at Gidan Belu community abount 300 m from the mines of the company, which is endowed with limestone, similar to the alpha activity measured from the ground water around Obajana cement company, Northcentral Nigeria especially for gross alph (Bello *et al.*, 2018). In that study alpha activity obtained ranged from 0.003±0.01 BqL^{-1} to 0.053±0.03 BqL^{-1}, while the beta activity was somewhat high in the range of 0.293±0.059 to 39.960±11.30 BqL^{-1}. The gross alpha activity and gross beta activity measured in this study are also lower than those recorded in tap water from Niger Delta region where mean activity values are 0.100±0.013 BqL^{-1} and 8.9±0.2 BqL^{-1}

respectively for gross alpha and gross beta (Agbalagba *et al.*, 2013) and for ground water in Ado-Ekiti where gross alpha and gross beta activities are 0.589±0.36 BqL^{-1} and 0.236±0.019 BqL^{-1} respectively (Fassea, 2013). With the exception of 0.131±0.01 BqL^{-1} for gross alpha activity concentration in water samples from Gidan Gamba, the results obtained in all the communities sampled were lower than the WHO, 2004 recommended limits of 0.1 BqL^{-1} and 1.0 BqL^{-1} for gross alpha and gross beta respectively.

Table 1: Activity concentration due to gross alpha and beta in the water samples

SAMPLE ID	Type of sample	Coordinates		Alpha Conc. (BqL^{-1})	Beta Conc. (BqL^{-1})
		Latitude (N)	Longitude (E)		
GB 1	Well water	13°02´45.2''	5°10´58.9''	0.009±0.001	0.029±0.002
GB 2	Borehole water	13°02´44.1''	5°10´58.2''	0.029±0.020	0.109
GG 1	Well water	13°02´41.9''	5°10´59''	0.131±0.010	0.273±0.020
GG 2	Well water	13°03´40.4''	5°11´58.7''	0.069±0.040	0.083±0.013
AR 1	Borehole water	13°04´10.5''	5°03´43.8''	0.033±0.011	0.062±0.011
AR 2	Well water	13°05´5.3''	5°03´43''	0.049±0.012	0.132±0.020
KB 1	Well water	13°05´58.7'	5°03´38''	0.032±0.011	0.098±0.012
KB 2	Borehole water	13°05´29.3''	5°03´6.2''	0.045±0.012	0.268±0.021
MS 1	Seepages	13°03´38.4''	5°10´26.5''	0.023±0.010	0.071±0.011
MS 2	Seepages	13°03´40.4''	5°10´30''	0.039±0.012	0.243±0.022
CS 1	Borehole water	13°04´0.6''	5°10´42.7''	BDL	0.008±0.001
CS 2	Well water	13°04´12.7''	5°10´42.7''	BDL	0.007±0.001

BDL= Below detection limit

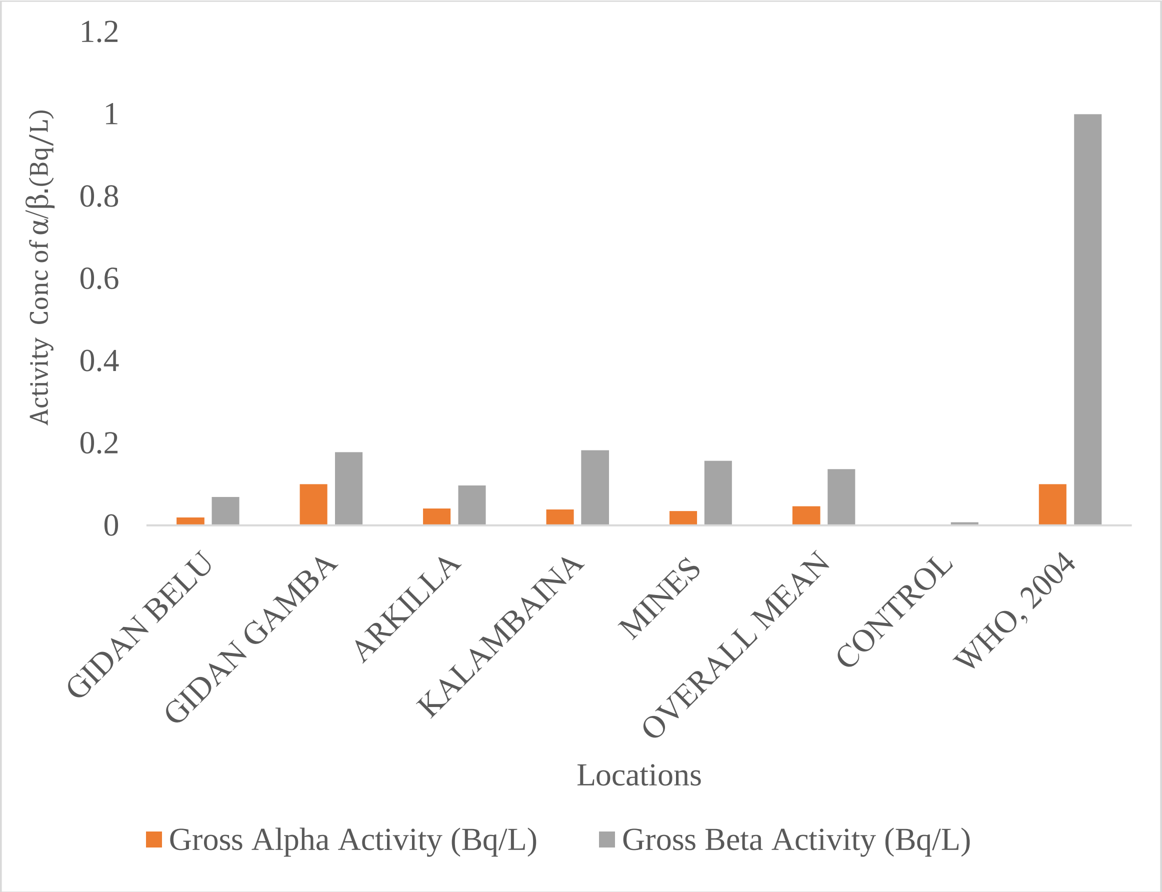

Figure 2: Mean gross alpha and gross beta activity concentrations in water

The result of alpha activity was lower than the result of 0.01 BqL^{-1} to 6.00 BqL^{-1} from survey of gross alpha radioactivity in bore hole and well water in Sokoto city (Saidu and Ike, 2013).

Table 2 shows the consequential estimated annual effective doses due to the activity concentrations due to gross alpha and gross beta using Equations 6 and 7 for adult and children respectively. The annual effective dose calculated for adults' ranges from 0.039 to 0.918 mSvy^{-1} with mean value of 0.225 mSvy^{-1} while for children it ranges from 0.010 to 0.230 mSvy^{-1} with mean value of 0.060 mSvy^{-1}. The highest value was recorded at Gidan Gamba due to the presence of loamy soil which is rich in alpha and beta emitter radionuclides. The least effective dose both for adults and children were recorded at Gidan Belu, community endowed with relatively high limestone deposit. The International Commission on Radiological Protection (ICRP) recommended limit of annual effective dose of 0.1 mSvy^{-1} was however higher than obtained results from all the communities studied except Gidan Gamba which recorded about 0.918 and 0.230 mSvy^{-1} for children and adults respectively. Although, there could be no radiation health risk for all the communities while long term exposure mostly at Gidan Gamba community is that of concern.

Table 2: Annual effective dose due to gross alpha and gross beta activity concentrations in water

		AED due to gross α activity(mSvy^{-1})		AED due to gross β activity (mSvy^{-1})		Total AED dose (mSvy^{-1})	
S/No.	LOCATION	Adults	Children	Adults	Children	Adults	Children
1.	GIDAN BELU	0.004	0.001	0.035	0.009	0.039	0.010
2.	GIDAN GAMBA	0.020	0.005	0.090	0.022	0.918	0.230
3.	ARKILLA	0.008	0.002	0.049	0.012	0.057	0.014
4.	KALAMBAINA	0.009	0.002	0.092	0.023	0.100	0.025
5.	MINES	0.007	0.002	0.079	0.019	0.009	0.022
	OVERALL MEAN	**0.009**	**0.002**	**0.069**	**0.017**	**0.225**	**0.060**
	ICRP (2007)	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**

CONCLUSION

Gross alpha and gross beta activity concentrations in samples of ground water from cement producing area of Sokoto state was measured using non-gas proportional counter. The gross alpha and beta activity concentrations in the water samples collected from the study area were within the WHO recommended safe limit of 0.1 and 1.0 BqL^{-1} respectively. Meanwhile, results of control samples were generally lower than those from the study area vouching some influence of the company's activities to the surrounding water sources. Community of Gidan Gamba endowed with rich loamy deposit recorded the highest value. Annual effective dose was calculated for children and adults from the gross alpha and beta activity concentration. The results showed that the except for Gidan Gamba, reference dose level of 0.1 mSvy^{-1} consumption of water was not exceeded in all the communities sampled. This implies that ground water from cement producing area of Sokoto has not been contaminated by the radionuclides in the mineral deposit in the area. Meanwhile, the study recommends inclusion of techniques such as reverse osmosis or ion exchange in the ground water from the study area to remove excess dissolved mineral radionuclides from the water in order to reduce radiological burden to the populace, especially of Gidan Gamba.

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