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AN ASSESSMENT OF NATURAL RADIOACTIVITY IN GROUNDWATER AND ITS HEALTH IMPLICATIONS IN KATSINA METROPOLIS, KATSINA STATE, NIGERIA

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ABSTRACT

. The World Health Organization's radiological water quality protocol was observed to screen samples of groundwater from Katsina, a semi-arid region part of northern Nigeria, for radiological safety analysis. Initially, the gross alpha and gross beta activity concentrations as measured by an eight channel gas flow proportional counting system indicated some parts of the study area to have elevated alpha and beta activity concentrations when compared with the International Commission on Radiological Protection (ICRP 1991) Maximum Acceptable Values (MAVs) of 500 Bqm^{-3} for alpha; $1,000 \text{ Bqm}^{-3}$ for beta activity concentrations. This prompts the need for further screening. In this respect, gamma spectroscopy was employed to evaluate the natural radioactive materials responsible for the elevated alpha and beta activity concentration values. Subsequently, United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) Dose Conversion Factors (DCF) were used to estimate the committed effective dose so as to ascertain the health risk level of using the water for drinking purposes.

1.0 Introduction

NORM, an acronym for naturally occurring radioactive materials, refers to the long-lived radioactive elements such as uranium, thorium and radioactive potassium (K-40) and their decay products, such as radium and radon that existed since the formation of the earth. These elements have always been present in the earth's crust and subsequently, in all environmental media (soil, air and water). Their presence makes them inevitably ingested into humans through food and drinking water (Alam 1999; Dalma, Cevik et

al. 2006; Gruber, Maringer et al. 2009). Evidences from both human and animal studies also shows that radiation exposure at low to moderate doses such as those from drinking water may increase the long-term incidence of cancer (Collman, Loomis et al. 1991; Amrani and Cherouati 1999; Abo, Manal et al. 2008). Due to the possible adverse effect from ingestion of radio-nuclides, through drinking water, a standard need to be set in order to curb the unwanted radiation exposure to human.

Many countries adopt the WHO recommendation of reference dose level [RDL] of committed effective dose of 0.1 mSv from one year's consumption of drinking water (WHO 1988). The RDL of 0.1 mSv is equal to 10% of the dose limit for members of the public, recommended by the ICRP (1991) and the International Basic Safety Standards (IAEA, 1996) and are acceptable to most WHO Member States (Bonotto and Bueno 2008).

In arid and semi-arid regions, such as the study area, evapotranspiration rates are much high, recharge is less, flow paths longer and residence times much greater and hence much higher levels of natural mineralization. Thus the major ion contents and Total Dissolved Solids (TDS) are often high. In some desert regions, even if groundwater can be found it may be so salty (extremely high TDS) as to be undrinkable in some cases. The difficulty of meeting even the most basic domestic requirements can have serious impacts on health and livelihood. This prompts the need to always screen domestic water supply from groundwater sources that are often utilized in arid regions. The WHO radiological water quality protocol was followed to screen samples of groundwater from Katsina, a semi-arid region of northern Nigeria, for radiological safety. The result shows elevated gross alpha and gross beta values exceeding the

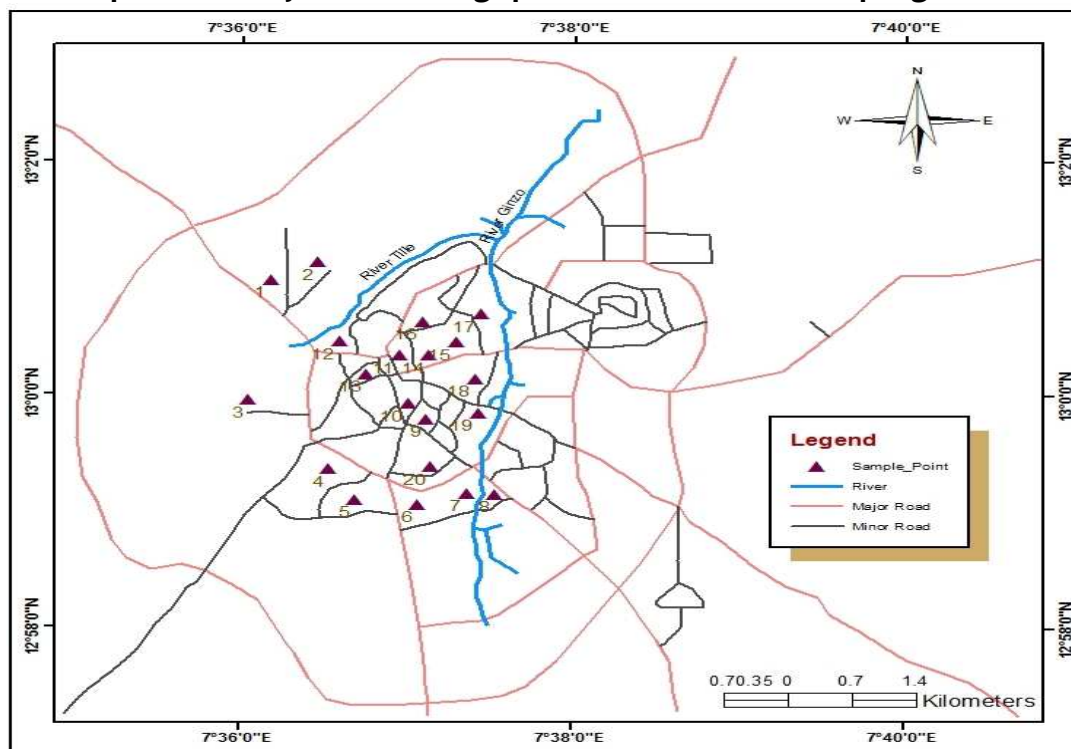
WHO maximum contaminants levels of 500 and 1000 Bq m⁻³ respectively. The results of this segment of the work was earlier reported (Muhammad, Jaafar et al. 2010). In the present work, gamma spectroscopy was employed to determine the natural radioactive materials responsible for the elevated alpha and beta activity concentration values. Subsequently, UNSCEAR dose conversion factors (DCF) were used to estimate the committed effective dose so as to ascertain the health risk level of using the water for drinking purposes.

2.0 Materials and Methods

2.1 Location of Sampling Points

AGPS was used to measure the geographical coordinates of the sampling sites, clean polythene containers were used to collect groundwater from the sites. The samples were then immediately brought to the laboratory for analysis. Guidelines provided by international organization for standardization on water quality sampling were strictly adhered to (ISO 2006). To prepare water samples for gamma spectroscopy, 500 ml of each sample was acidified with 10 ml of concentrated HNO₃ (analytical grade) (ISO 2005) and then sealed in the polythene counting sample container and kept for a period of at least four weeks prior to counting.

Figure 1: Map of the study area showing spatial distribution of Sampling Points



(Source: Department of Geography UMYU, Katsina)

2.2 Gamma spectroscopic system

Gamma spectroscopic measurements were carried out using a high efficiency 3" x 3" Thallium doped, sodium iodide [NaI(Tl)] scintillation detector (Ortec, USA), with serial number 101909H connected to a 3" (B76D01W N 2034257) PMT photomultiplier tube. The set-up was coupled to a multi channel analyzer (MCA). The detector was enclosed in a 10 cm lead shield to reduce background radiation in the counting environment. The system has relative efficiency and resolution of about 50% and 7.2% respectively at energy of 0.662 MeV (^{137}Cs). These are considered adequate to distinguish the gamma ray energies of interest in this work. The spectral analysis and peak fitting were performed using FitzpeakNaI(Tl) (low resolution) gamma calibration and analysis software developed by JF Scientific UK. This software is specially optimized to be used for low resolution gamma detector NaI(Tl). The energy calibration was carried out using IAEA certified standards of

known energies such as ^{60}Co , for $E_{\gamma} = 1332.5$ and 1173.2 keV, and ^{137}Cs , for $E_{\gamma} = 661.6$ keV. The efficiency calibration was also performed by using IAEA certified ^{152}Eu standard (ISO 2007) for $E_{\gamma} = 121.8, 224.7, 344.3, 778.9, 964.0, 1085.8, 1112.0$ and 1408.0 keV. A counting time of 86400 s was allowed for both background and sample due to the low emission nature of the samples. The activity concentrations of the radio-nuclides in the samples were determined from their respective gamma-ray lines or gamma-ray lines emitted from their decay products. The gamma line of 1460.8 keV was used directly to determine ^{40}K . The weighted mean activity concentrations from gamma lines of 911.1 keV (^{228}Ac) and 583.1 keV (^{212}Pb) were used to determine ^{232}Th . The gamma lines of 351.9 keV (^{214}Pb) and 609.3 keV (^{214}Bi) were used to determine ^{238}U and 186.1 keV (^{226}Ra) gives the activity concentration of ^{226}Ra as a natural source.

2.3 Committed effective dose

Estimation of committed effective dose E_d ($Sv\ y^{-1}$) to an individual due to the consumption of the natural radio-nuclides present in the drinking water was done using equation 1.1 (Alam 1999). The WHO A_i values of 230, 330 and 730 litres for infants(1-2 years), children (>7-12 years) and adults (>17 years) respectively were used (WHO 1988; Ajayi and Achuka 2009).

$$E_d = A_c * A_i * C_f$$

1

where A_c is the radionuclide activity concentration ($Bq\ l^{-1}$), A_i is the annual intake of water ($l\ y^{-1}$) and C_f is the dose conversion factor for the radionuclide ($Sv\ Bq^{-1}$). The dose conversion coefficients provided by UNSCEAR 2000 report(UNSCEAR 2000) were also used for the dose estimation. The total committed effective dose D ($Sv\ y^{-1}$) to an individual was established by summing up the contributions from all radio-nuclides present in the water samples as given by equation 1.2.

$$D = \sum A_c * A_i * C_f$$

2

3.0 Results and Discussion

The activity concentration of natural radio-nuclides in the groundwater from the study area is presented in table 1. Table 2 presents the estimated total committed effective dose resulting as a consequence of direct ingestion of dissolved radio-nuclides in the groundwater. Table 3 compares the results of the present study with those from other parts of the world.

The world annual natural radioactivity level, including external exposure, consumption of food and water containing natural radio-nuclides, and inhalation of radon with its daughter products, amounts on average to 2.4 mSv, with a range from 1 to 10 mSv(UNSCEAR 2000). The United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) report also indicated that the average worldwide exposure to natural sources in foods and drinking water is 0.29 mSv y^{-1} (about 0.17 mSv y^{-1} from ^{40}K and about 0.12 mSv y^{-1} from Uranium and Thorium)(UNSCEAR 2000).

Table 1 Activity concentration of natural radionuclides in the groundwater sources

S/ N	Location		Activity Concentration (Bq l ⁻¹)				
	Location	Geographical coordinates	²³⁸ U	²³² Th	⁴⁰ K	²²⁶ Ra	
1.	Dutsin Safe Low-cost	N13° 00' 20.1" 10.1"	E7° 35'	0.48±0.0 35	0.39±0.0 21	0.79±0.0 42	0.29±0.01 2
2.	Dutsin Safe extension	N13° 00' 11.7" 00.9"	E7° 35'	0.49±0.0 28	0.54±0.0 33	0.78±0.0 67	0.28±0.02 1
3.	Fed. Medical Centre	N12° 59' 06.4" 38.8"	E7° 34'	0.22±0.0 11	1.30±0.0 23	0.91±0.0 72	1.09±0.07 3
4.	Sokoto Rima	N12° 58' 41.5" 37.3"	E7° 35'	0.29±0.0 21	0.17±0.0 11	1.16±0.0 91	1.39±0.07 7
5.	Abbatoir	N12° 58' 24.3" 27.7"	E7° 35'	0.22±0.0 12	0.04±0.0 03	0.91±0.0 82	1.09±0.08 1
6.	Central Market	N12° 58' 16.3" 06.0"	E7° 36'	0.34±0.0 21	0.23±0.0 12	1.32±0.0 88	1.68±0.09 3
7.	SabuwarUngu wa	N12° 58' 11.0" 32.7"	E7° 36'	0.31±0.0 17	0.27±0.0 23	1.20±0.0 76	1.54±0.08 2
8.	Bread	N12° 58' 23.1" 50.4"	E7° 36'	0.78±0.0 76	0.64±0.0 43	0.39±0.0 31	1.48±0.07 6
9.	Garama Quarters	N12° 59' 07.9" 19.9"	E7° 36'	0.81±0.0 65	0.66±0.0 17	4.07±0.0 89	1.55±0.08 8
10.	SabonLayi	N12° 59' 13.0" 19.1"	E7° 36'	0.39±0.0 22	0.15±0.0 14	0.64±0.0 67	0.22±0.03 3
11.	Emir's Palace	N12° 59' 42.5" 01.0"	E7° 36'	0.50±0.0 31	0.49±0.0 51	0.89±0.0 73	0.32±0.02 3
12.	FarinYaro	N12° 59' 48.3" 30.5"	E7° 35'	0.44±0.0 62	1.20±0.0 87	0.78±0.0 55	0.28±0.02 2
13.	UnguwarYari	N12° 59' 28.9" 36.0"	E7° 35'	0.04±0.0 03	1.11±0.09 6	0.71±0.0 76	0.25±0.01 2
14.	'Yaradua	N12° 59' 38.7" 18.7"	E7° 36'	0.47±0.0 53	0.24±0.0 19	0.71±0.0 81	0.25±0.01 8
15.	Tudun Wada	N12° 59' 54.4" 26.4"	E7° 36'	0.43±0.0 33	0.12±0.0 23	0.70±0.0 73	0.25±0.02 1
16.	School of Nursing	N13° 00' 04.2" 16.3"	E7° 36'	0.43±0.0 43	0.14±0.0 12	0.68±0.0 56	0.25±0.01 4
17.	FilinSamji	N13° 00' 22.4" 35.4"	E7° 36'	0.46±0.0 36	0.33±0.0 23	0.78±0.0 55	0.28±0.02 2
18.	DutsinAmare	N12° 59' 30.2" 39.6"	E7° 36'	0.42±0.0 21	0.21±0.01 8	0.73±0.0 47	0.27±0.01 7
19.	KofarMarusa	N12° 59' 19.1" 33.2"	E7° 36'	0.04±0.0 32	0.02±0.0 03	0.60±0.0 44	0.22±0.011
20.	Shararrar Pipe	N12° 58' 38.1" 23.5"	E7° 36'	0.49±0.0 33	0.30±0.0 16	0.84±0.0 67	0.31±0.021

For prolonged exposure situations in case of all environmental radioactive sources, including natural and human-made sources, the International Commission on Radiological Protection (ICRP) recently recommended a generic intervention level of annual dose of 10 mSv as the level below which intervention is unjustified, taking into account radiological, economic and social factors (Wrixon 2008). The world

health organization in its guidelines for drinking water quality, adopted the International commission on radiological protections' recommendation of reference dose level (RDL) of the committed effective dose, to be equal to 0.1mSv from 1 year's consumption of drinking-water (from the possible total radioactive contamination of the annual drinking-water consumption).

Table 2 Estimated age dependent total committed effective dose (mSv y⁻¹) in groundwater due to natural radionuclides in the area

S/N	Location	Geographical coordinates		Infants (1-2 y)	Children (>7-12 y)	Adults (>17 y)
1.	Dutsin Safe Lowcost	N13° 00' 20.1"	E7° 35' 10.1"	0.14	0.14	0.15
2.	Dutsin Safe extension	N13° 00' 11.7"	E7° 35' 00.9"	0.16	0.15	0.18
3.	Fed. Medical Centre	N12° 59' 06.4"	E7° 34' 38.8"	0.42	0.43	0.47
4.	Sokoto Rima	N12° 58' 41.5"	E7° 35' 37.3"	0.39	0.41	0.35
5.	Abbatoir	N12° 58' 24.3"	E7° 35' 27.7"	0.30	0.31	0.26
6.	Central Market	N12° 58' 16.3"	E7° 36' 06.0"	0.46	0.49	0.42
7.	SabuwarUnguwa	N12° 58' 11.0"	E7° 36' 32.7"	0.43	0.46	0.39
8.	Nakowa Bread	N12° 58' 23.1"	E7° 36' 50.4"	0.46	0.49	0.46
9.	Garama Quarters	N12° 59' 07.9"	E7° 36' 19.9"	0.51	0.52	0.49
10.	SabonLayi	N12° 59' 13.0"	E7° 36' 19.1"	0.12	0.10	0.10
11.	Emir's Palace	N12° 59' 42.5"	E7° 36' 01.0"	0.18	0.16	0.19
12.	FarinYaro	N12° 59' 48.3"	E7° 35' 30.5"	0.21	0.20	0.28
13.	UnguwarYari	N12° 59' 28.9"	E7° 35' 36.0"	0.18	0.18	0.24
14.	'Yaradua	N12° 59' 38.7"	E7° 36' 18.7"	0.10	0.10	0.11
15.	Tudun Wada	N12° 59' 54.4"	E7° 36' 26.4"	0.10	0.10	0.10
16.	School of Nursing	N13° 00' 04.2"	E7° 36' 16.3"	0.10	0.10	0.10
17.	FilinSamji	N13° 00' 22.4"	E7° 36' 35.4"	0.12	0.12	0.14
18.	DutsinAmare	N12° 59' 30.2"	E7° 36' 39.6"	0.11	0.11	0.11
19.	KofarMarusa	N12° 59' 19.1"	E7° 36' 33.2"	0.08	0.07	0.06
20.	Shararrar Pipe	N12° 58' 38.1"	E7° 36' 23.5"	0.15	0.14	0.15

Comparing the results of this study with other sources from other parts of the world, the mean measured activity concentration values of 0.43, 0.52 and 1.02

Bq l⁻¹ for ²³²Th, ⁴⁰K and ²²⁶Ra respectively are well below the reported concentrations of 12, 12 and 29 Bq l⁻¹ of (untreated) lake water from Biseni, Nigeria.

In water used for drinking and other domestic purposes, the mean measured activity concentration values on the other hand, are above the earlier reported values for bottled water from Pakistan as well as the tap water from Egypt, but the

values (^{226}Ra and ^{40}K) from this area are still far below the earlier reported values for well drinking water from Akure Nigeria, where high level of radium was discovered.

Table 3: Natural radioactivity in water from other parts of the world

Area	Type of Source	Mean specific activity (Bq l ⁻¹)			Reference
		²³² Th	²²⁶ Ra	⁴⁰ K	
Egypt	Tap water	0.008	0.0157	0.152	(Amin, Khalil et al. 2011)
Islamabad, Pakistan	Bottled water	0.0113	0.052	0.0409	(Fatima, Zaidi et al. 2007)
Biseni, Nigeria	Lake water	12	12	29	(Agbalagba and Onoja 2011)
Akure, Nigeria	Well water	NR	7.15	13.54	(Ajayi and Owolabi 2008)
Chittagong, Bangladesh	Well and tap	0.19	0.043	4.16	(Alam 1999)
Katsina, Nigeria	Groundwater	0.43	0.52	1.02	This work

NR- not reported

Consequently, the total committed effective dose due to one year's direct ingestion of the groundwater from the study area was estimated to vary from 0.07 to 0.46, 0.08 to 0.49 and 0.06 to 0.49 for infants, children and adults respectively. This indicates that the value in most of the groundwater sources seems to exceed the reference dose values of 0.1 mSv y⁻¹ as recommended by the WHO. However, the total committed effective dose estimated in all the samples considered is below 1 mSv y⁻¹, which is the 10% of the level above which intervention is justified taking into account radiological, economic and social factors.

4.0 Conclusion

The results of this study provides a baseline data of the natural radioactivity levels in the groundwater resources abundantly utilised for drinking and other domestic purposes by inhabitants of Katsina, a semi arid region in northern Nigeria. Comparatively, the moderate natural activity concentration

values in groundwater from arid and semi arid regions such as the study area are attributable to the nature of the water sources, that is, less recharge and high residence time resulting in more dissolved solids accumulation in the water. Despite the fact that the concentrations of natural radioisotopes and subsequent committed effective doses in many samples were substantially higher than those in other populations, most still remained low when compared with generic intervention level. The magnitude of risk expected in our study is therefore small. Radionuclides screening as well as the use of best available technologies (BAT) such as ion exchange, reverse osmosis or lime softening (as recommended by USEPA) for areas where the natural radionuclides concentrations results in committed effective dose that exceeds RDL are recommended in order to safeguard the members of the public from radiation exposure above recommended limits.

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