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Gross Alpha and Beta activity Concentrations and Committed Effective Dose due to Intake of Groundwater in Ado-Ekiti Metropolis; the Capital City of Ekiti State, Southwestern, Nigeria

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Abstract
The gross alpha and beta activity concentrations in dug well water in Ado-Ekiti, Ekiti State, southwestern Nigeria were determined in order to estimate the committed effective dose from intake of the alpha and beta emmiters. The Gas-flow proportional counter (Eurisys Measure IN20 low-background multiple (eight) channel counter was employed in the analysis of the gross alpha and beta. The mean gross alpha and beta activity in the dug well water samples across the areas which covers the land area in the town ranged from 0.216 Bq/L to 1.299 Bq/L with a mean value of 0.589 ± 0.36 Bq/L and 0.064 Bq/L to 0.582 Bq/L with a mean value of 0.236 ± 0.19 Bq/L respectively. The estimated mean committed effective dose value of 0.12 ± 0.08 mSv/y and 0.07 ± 0.05mSv/y for an adult and a child respectively are within 0.1 mSv/y reference dose level (ICRP, 1991).
Keywords: Committed effective dose, gross alpha, dug-well, water, Activity concentration.

1.0 Introduction

Natural radioactivity is always present in the environment. Water**,** especially ground water, is not free of radioactive isotopes from naturally decaying series of ^{238}U, ^{232}Th and ^{40}K. It is natural to find radionuclides in drinking water. They can get into water as it comes in contact with natural radioactive materials in the soil. The activity concentrations of natural radionuclides in groundwater are connected to the activity concentrations of ^{238}U and ^{232}Th and their decay products in the ground and bedrock (Vesterbacka, 2007). This is due to ground water reacting with the ground and bedrock and releasing quantities of dissolved components that depend on the the mineralogical and geochemical composition of the soil and rock, chemical composition of the water, the degree of weathering of the rock, redox conditions and the residence time of ground water in the soil and bedrock. In addition to the radiation dose from the ingested ^{222}Rn, the water-born ^{222}Ra is released into indoor air during water usage and inhaled ^{222}Ra daughters affect lungs (Vesterbacka, 2007).

The activity concentration of natural radionuclides depends on the water source. In the surface water, activity concentrations are typically very low. Occasionally increased concentrations are found in dug –well water, whereas in drilled-well water activity concentrations can be exceptionally high. ^{238}U has a special position. Also the concentration of dissolved substances in waters is depending on the season. As it is well known, this concentration increases in summer due to the high evaporation rates and the increase of the solubility of the salts due to the higher temperatures of the water. Consequently there is expected to be an increase in the uranium concentration in those waters sampled in summer (Kehagia et al., 2007). In addition to radioactivity, it has a chemical toxicity that predominately affects the kidneys (Auvinen et al., 2002, Kurttio et al., 2005). Therefore, measuring the radioactivity in drinking water is of great interest in environmental studies (Ajayi and Owolabi, 2008). A gross alpha test is the first step in determining the level of radioactivity in drinking water. This test serves as a preliminary screening device and determines whether additional testing is advisable (Kehagia et al., 2007). Gross alpha is more of a concern than gross beta for natural radioactivity in water as it refers to the radioactivity of Th, U, Ra as well as Rn and descendants (EPA, 1997).

If the gross alpha and gross beta are less than 0.1 and 1.0 Bq/L respectively, it can be assumed that the TID is less than the parametric indicator value of 0.1 mSv/year and no further radiological investigation is needed. If the gross alpha activity exceeds 0.1 Bq/L or the gross beta activity exceeds 1.0 Bq/L, analysis for specific radionuclides is required (WHO, 1993).

This study helps in understanding a quantitative detection of gross alpha and beta radioactivity which is important for a quick surveying of both natural and anthropogenic radioactivity in dug well water in Ado-Ekiti metropolis.

2.0 Materials and Methods

2.1 Sample Collection and Preparation

Seventy water samples were collected from dug well within the Seven areas namely: Adebayo, Ajebandele, Ajilosun, Basiri, Dallimore, Irona and Odo-Ado in Ado-Ekiti, the capital city of Ekiti State in Southwestern region of Nigeria. The samples were collected in 2-litre plastic containers with about 1% air space left for thermal expansion. The dug well water samples were collected manually in the early hours of the day from community wells of varying depths (5-10m). To minimize contamination, the containers were first rinsed three times with sample water before use. The water samples were immediately acidified with 20ml ± 1ml of nitric acid per liter of sample collected to minimize the absorption of radioactivity into the walls of the containers (ISO, 9697 & 9698: 1992a). The samples were then tightly covered and kept in the laboratory. For purposes of analysis the samples were slowly evaporated without boiling, down to a volume of 50ml at a furnace temperature of 60^0C. The residue was then transferred to a stainless-steel planchet, dried and allowed to equilibrate with ambient temperature and weighed. The counting time was 30000s while the screening technique is as reported by (Ezekiel et al., 2013) and in agreement with ISO, 9697 and 9698: 1992b guidelines.

2.2 Counting Equipment

The gas-flow-proportional counter (Eurisys Measure- IN20) eight channel counter at the Material Laboratory, Centre for Energy Research and Training (CERT), Ahmadu Bello University (ABU), Zaria was used for the counting. Each counter channel has a window thickness of 450µgcm-3 and a diameter of 60mm. The chambers are covered with lead whose thickness can be varied. The detectors are operated within the radiation environment of < 101µradh^{-1}. The system isconnected to a microprocessor loaded with a spread sheet programme (Quarttro-Pro) and graphic programme (Multiplan). The system can be operated at a bias voltage (~1100V with P10 gas: argonmethane of 10%) where only alpha particles are detected, referred to as 'alpha-only' mode.

2.3 Detector Calibration

The alpha standard was ^{239}Pu with a half life of 24110years, while the beta standard was ^{90}Sr with a half life of 28years. Their respective activities were calculated at the time of the calibration and are presented in Tables1 and 2 respectively. These standards were certified by CERCA LEA Laboratories in France with certification numbers CT 001/1285/001920-1927 and CT 1271/00/1778- 1783, respectively.

Plateau test was run with the manufacturer's calibration standards (^{239}Pu and ^{90}Sr) whose activities ranges from 133.29 to 185.51Bq and 92.31 to 103.68Bq, respectively in all the three operating modes. This test was run for 1800s for five cycles. The operational efficiencies of the eight channels of the counter were thus obtained as presented in Table 3(Ezekiel et al., 2013).

2.4 Estimation of committed effective dose

Radionuclide may reach the gastrointestinal tract directly by ingestion or indirectly by transfer from the respiratory tract. From small intestine (S1) the radionuclide can be absorbed to the body fluids.

On average, adults are considered to consume two litres of water per day, while children are considered to consume only one

The committed quantities, because of small effective half-lives, are practically realized within one year after intake (Turner,1995). In this work, the effective dose over one year was calculated using the following relation.

$$E = I\,AC \times 365 \qquad (1)$$

Where I is the daily water consumption in l/day, A is the activity/l; C is a dose conversion factor in Sv/Bq. Dose conversion factors used to calculate the internal radiation exposure by ingestion of radionuclide by IAEA (2003) were considered, see Table (4).

3.0 Results, Discussion and Conclusion

3.1 Results and Discussion

The range and mean gross alpha and beta activity concentrations of ground water; dug well water samples in Ado-Ekiti metropolis in Ekiti State, Nigeria are presented in Table 5. The dug well water samples from Dallimore area of the town exhibits the highest gross alpha activity concentration values which ranged from 1.104 Bq/L to 1.637 Bq/L with a mean value of 1.299 ± 0.189 Bq/L. The gross beta activity concentration value is highest in Adebayo area which ranged from 0.547 Bq/L to 0.635 Bq/L with a mean value of 0.582 ± 0.027 Bq/L. The highest mean gross alpha activity concentration value at Dallimore may be attributed to the presence of the rocks and the geological formation of the area. The area is covered with more rocks and hills compare to other areas within the Ado-Ekiti metropolis. The mean gross alpha and beta activity in the dug well water samples across the areas which covers the land area in the town ranged from 0.216 Bq/L to 1.299 Bq/L with a mean value of 0.589 ± 0.36 Bq/L and 0.064 Bq to 0.582 Bq/L with a mean value of 0.236 ± 0.19 Bq/L respectively. However, the dug well water samples within the Ado-Ekiti metropolis seem to be more enriched in alpha emmiters as shown in the Fig. 1. This may also suggest that there would be an enhanced internal exposure to radioactivity. Statistical analysis of the gross alpha and beta activity concentrations values of the dug well water samples gives the p-value of 0.04 which is less than 0.05% confidence level, this implies that there is significant difference in the gross alpha and beta activity concentration values across the town. Though the spacial distribution of the gross alpha and beta activity concentrations were not considered in this study, the results show that the values significantly vary within the town. The results also show that there is a positive correlation between gross alpha and beta activity concentration with a regression value of 0.376. This shows that different radionuclides are responsible for alpha and beta activities in the water samples (Ezekiel et al., 2013).

The mean gross alpha activity concentration in this study is 45% higher than the WHO 0.1 Bq/L recommended level, while the mean gross beta activity concentration is 23.6% lower than the WHO recommended level of 1.0 Bq/L.

The committed effective dose is based on the risks of radiation induced effects and the use of the International Commission on Radiological Protection (ICRP) metabolic model that provides relevant conversion factors to calculate effective doses from the total activity concentration of radionuclides measured. The committed effective doses due to gross alpha are estimated using equation 1. The conversion factors of 1.5×10^{-6} for children and 2.8×10^{-7}. It is assummed that an adult consumes about 2 litres of water daily which corresponds to 730 L/y, while a child is assumed to consume about 200 L/y (Fernandez et al., 1992, WHO, 2004). The estimated committed effective dose values are presented in Table 5. The committed effective dose due to the gross alpha activity concentrations within Ado-Ekiti township ranged from 0.04 mSv/y to 0.27 mSv/y with a mean value of 0.12 ± 0.08 mSv/y for adult while the values for children ranged from 0.01 mSv/y to 0.18 mSv/y with a mean value of 0.07 mSv/y. The estimated mean committed effective dose are within 0.1 mSv/y reference dose level (ICRP, 1991). This study therefore shows that the consumption of dug well water does not pose any health burden to the population. The committed effective dose values obtained compare well with values obtained in the literatures as reported (Elena et al., 2007, Tettey et al., 2013, Aleissa and Islam, 2013, Ezekiel et al., 2013).

3.2 Conclusion

The study determined and evaluated the gross alpha and beta activity concentrations in the dug well water within Ado-Ekiti metropolis in Ekiti State, Nigeria. The gross alpha and beta activities vary significantly within the areas in the town which may be attributed to the geological formation of the town. The gross alpha and beta activity values compare well with values in literatures. The estimated mean committed effective dose value of 0.12 ± 0.08 mSv/y and 0.07 ± 0.05mSv/y for an adult and a child are within 0.1 mSv/y reference dose level (ICRP, 1991).

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Table1: The Alpha Standard Sources Serial Number and Activities at first Calibration and at the Moment.

Serial Number	Activity in (Bq) at 29/11/2000	Activity in (Bq) at 12/10/2010
EASB 20/50026	160.1	159.4
EASB 20/50050	170.3	170.0
EASB 20/50051	157.4	156.6
EASB 20/50052	133.3	133.0
EASB 20/50053	168.1	168.0
EASB 20/50054	185.5	185.1
EASB 20/50055	185.8	185.2
EASB 20/50056	168.3	168.0

Table2: The Beta Standard Sources Serial Number and Activities at first Calibration and at the Moment.

Serial Number	Activity in (Bq) at 22/11/2000	Activity in Bq) at 16/2/2010
EASB 20/14529	118.5	86.5
EASB 20/14530	117.7	86.4
EASB 20/14531	106.9	77.7
EASB 20/14533	105.5	78.0
EASB 20/14535	113.1	82.8
EASB 20/14536	106.9	77.3
EASB 20/14537	106.4	77.9
EASB 20/14539	105.1	77.0

Table 3: Channel efficiency calibration results

Detector No	Alpha only, α channel efficiency %	Beta (+α) β channel eff. %	α/β simultaneously β channel eff. %
01	35.34	46.47	29.22
02	35.85	35.39	19.79
03	164.68	74.50	227.79
04	36.87	38.79	23.25
05	34.41	40.67	20.69
06	34.74	42.94	23.44
07	524.91	5908.45	536.30
08	36.03	34.88	20.62
Average	**35.53**	**40.00**	**22.84**

TABLE 4. Ingestion: Committed Effective Dose per Unit Intake Via Ingestion (Sv/Bq) For Members of the Public.

Nuclide	Physical half-life	Age g ≤ 1 a	Age 1-2 a	Age 2-7 a	Age 7-12 a	Age 12-17a	Age >17 a
K-40	1.28 E+09 a	6.2 E-08	4.2 E-08	2.1 E-08	1.3 E-08	7.6 E-09	6.2 E-09
Pb-210	22.3 a	8.4 E-06	3.6 E-06	2.2 E-06	1.9 E-06	1.9 E-06	6.9 E-07
Pb-212	10.6 h	1.5 E-07	6.3 E-08	3.3 E-08	2.0 E-08	1.3 E-08	6.0 E-09
Pb-214	0.447 h	2.7 E-09	1.0 E-09	5.2 E-10	3.1 E-10	2.0 E-10	1.4 E-10
Ra-224	3.66 d	2.7 E-06	6.6 E-07	3.5 E-07	2.6 E-07	2.0 E-07	6.5 E-08
Ra-226	1.60 E+03 a	4.7 E-06	9.6 E-07	6.2 E-07	8.0 E-07	1.5 E-06	2.8 E-07
Ac-228	6.13 h	7.4 E-09	2.8 E-09	1.4 E-09	8.7 E-10	5.3 E-10	4.3 E-10
Th-228	1.91 a	3.7 E-06	3.7 E-07	2.2 E-07	1.5 E-07	9.4 E-08	7.2 E-08
Th-230	7.70 E+04 a	4.1 E-06	4.1 E-07	3.1 E-07	2.4 E-07	2.2 E-07	2.1 E-07
Th-231	1.06 d	3.9 E-09	2.5 E-09	1.2 E-09	7.4 E-10	4.2 E-10	3.4 E-10
Th-234	24.1 d	4.0 E-08	2.5 E-08	1.3 E-08	7.4 E-09	8.0 E-07	7.1 E-07
U-235	7.04 E+08 a	3.5 E-07	1.3 E-07	8.5 E-08	7.1 E-08	7.0 E-08	4.7 E-08
Bi-212	1.01 h	3.2 E-09	1.8 E-09	8.7 E-10	5.0 E-10	3.3 E-10	2.6 E-10
Bi-214	0.332 h	1.4 E-09	7.4 E-10	3.6 E-10	2.1 E-10	1.4 E-10	1.1 E-10
Cd-109	1.27 a	2.1 E-08	9.5 E-09	5.5 E-09	3.5 E-09	2.4 E-09	2.0 E-09

Table 5 Mean and Range gross alpha and beta activity concentrations in dug well water in Ado-Ekiti

Sample	No of Samples	Gross- α activity concentration (Bq/L)	Gross- β activity concentration (Bq/L)	Committed Effective dose (mSv/y) Adult	Committed Effective dose (mSv/y) Children
Adebayo	10	0.797 ± 0.013 (0.779 – 0.821)	0.582 ± 0.027 (0.547 – 0.635)	0.16	0.18
Ajebandele	10	0.402 ± 0.08 (0.327 – 0.540)	0.106 ± 0.03 (0.078 – 0.168)	0.08	0.03
Ajilosun	10	0.432 ± 0.08 (0.345 – 0.583)	0.109 ± 0.043 (0.072 – 0.185)	0.09	0.033
Basiri	10	0.518 ± 0.06 (0.455 – 0.650)	0.122 ± 0.03 (0.078 – 0.164)	0.11	0.04
Dallimore	10	1.299 ± 0.189 1.104 – 1.637	0.402 ± 0.022 (0.386 – 0.453)	0.27	0.12
Irona	10	0.457 ± 0.004 (0.251 – 0.650)	0.064 ± 0.004 (0.057 – 0.070)	0.09	0.01
Odo-Ado	10	0.216 ± 0.041 (0.183 – 0.231)	0.264 ± 0.029 (0.240 – 0.326)	0.04	0.07
Range	70	0.216 – 1.299	0.064 – 0.582	0.04 – 0.27	0.01 – 0.18
Mean		0.589 ± 0.36	0.236 ± 0.19	0.12± 0.08	0.07 ± 0.05

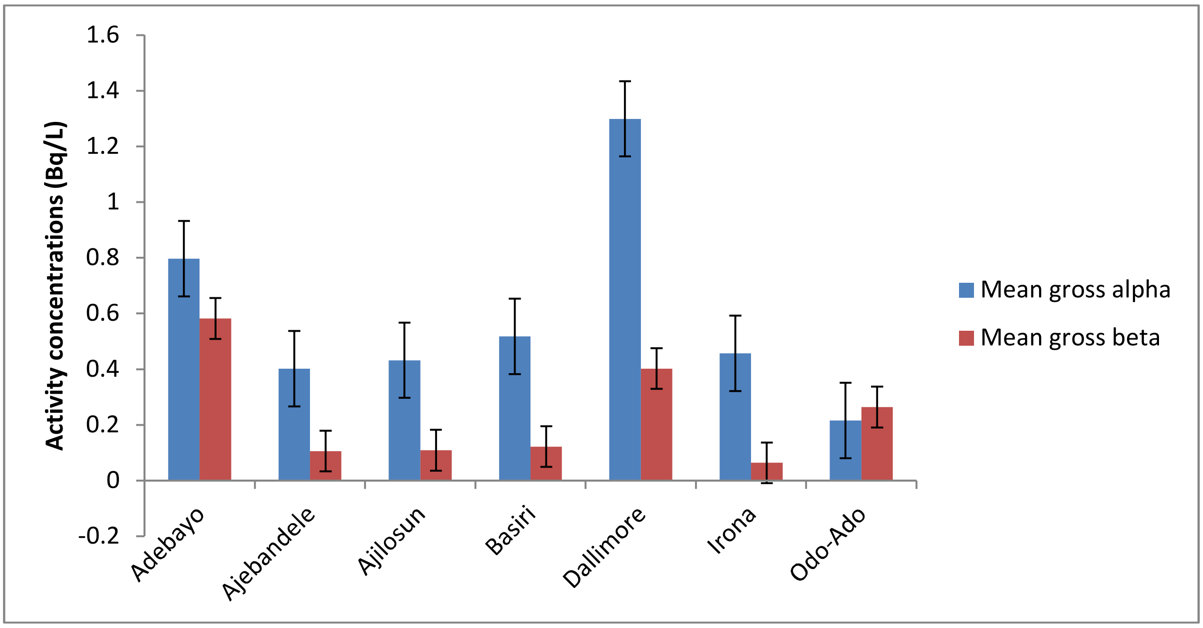

Fig. 1: The gross alpha and beta activities within Ado-Ekiti metropolis in Ekiti State