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EVALUATION OF THE RADIATION HAZARD INDICES AND EXCESS LIFE TIME CANCER RISK DUE TO NATURAL RADIOACTIVITY IN GROUND WATER IN MINING AREAS OF PLATEAU STATE.

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ABSTRACT

The radiological implications of water intake from ground water supply in mining areas of Plateau State have been estimated. Fifty eight ground water samples (23 boreholes and 35 well samples) were randomly taken in two litres plastic containers within the Naraguta Topo sheet 168 covering the mining areas. About 10ml of Nitric acid was added to each sample at the point of collection for preservation. The samples were later evaporated and transferred into planchets. They were then counted for gross alpha and beta activity concentrations using MPC-2000-DP. The results obtained showed that the range of alpha activity concentration varied from (0.110 – 1.550)Bq/l for borehole sample and (0.010 – 12.590)Bq/l for well samples. The range of beta activities concentration varied from (0.012 – 2.760)Bq/l for borehole samples and (0.020 – 14.640)Bq/l for well samples. The hazard indices and excess lifetime cancer Risk were evaluated. For borehole samples the mean value for AEDE, AGED and ELCR for alpha emitting radionuclides were 0.157mSv/yr 0.039 mSvr/yr and 0.548 x 10^{-3} respectively while beta emitting radionuclides had the mean values of 0.134mSv/yr, 0.668mSv/yr and 0.468 x 10^{-3} respectively. For well water samples, the mean values of AEDE, AGED and ELCR for alpha emitting radionuclides were 0.335mSv/yr, 0.084mSv/yr and 1.172 x 10^{-3} respectively while beta emitting radionuclides had mean values of 0.393mSv/yr, 1.964mSv/yr and 1.375 x 10^{-3} respectively. Almost all the values are above their acceptable standards. It can be concluded that there is a significant radiological hazards to the people in the study area which can be attributed to the mining activities that took place in the area.

Keywords: Gross alpha, Gross beta, Radiation hazard indices, excess lifetime cancer risk, Plateau State.

INTRODUCTION

The measurement of natural radioactivity in our environment allows the determination and assessment of population exposure to radiation. The occurrence of natural radionuclides in water depends on the waters origin as well human activities in the area, such as the geology of the area, tin mining and use of fertilizers in agriculture.

Industrial activities such as extraction and processing of minerals may cause the incorporation of radionuclides into the hydrosphere through surface or ground water (Pujol and Sanchez-cebeza, 2000). For groundwater (boreholes and wells), it depends on their presence and contents in lithological of solids aquifers or rocks known as geological materials particularly the Jos Plateau rock types amounts of radioactive elements such as Uranuim, thorium and potassium which may dissolve into ground water system during water/rock –soils interaction mechanism (Solomon, 2005).

Consumption of ground water with elevated amounts of natural radionuclides may increase the radioloxicity to human and internal exposure to radiation caused by the decay of the natural radionuclides taken into the body through ingestion as well as inhalation. The decay process leads to the release of several alpha and beta particles which are

responsible for the total radiation dose received from natural radioactivity as well as artificial (Karahan et al, 2000). Gross alpha and beta activities are usually represented by ^{238}U series, ^{232}Th series and non-series of ^{40}K respectively (Eric et al, 2013). Determination of gross alpha and beta activity concentration levels in groundwater are necessary for routine monitoring of radioactivity level in groundwater resources.

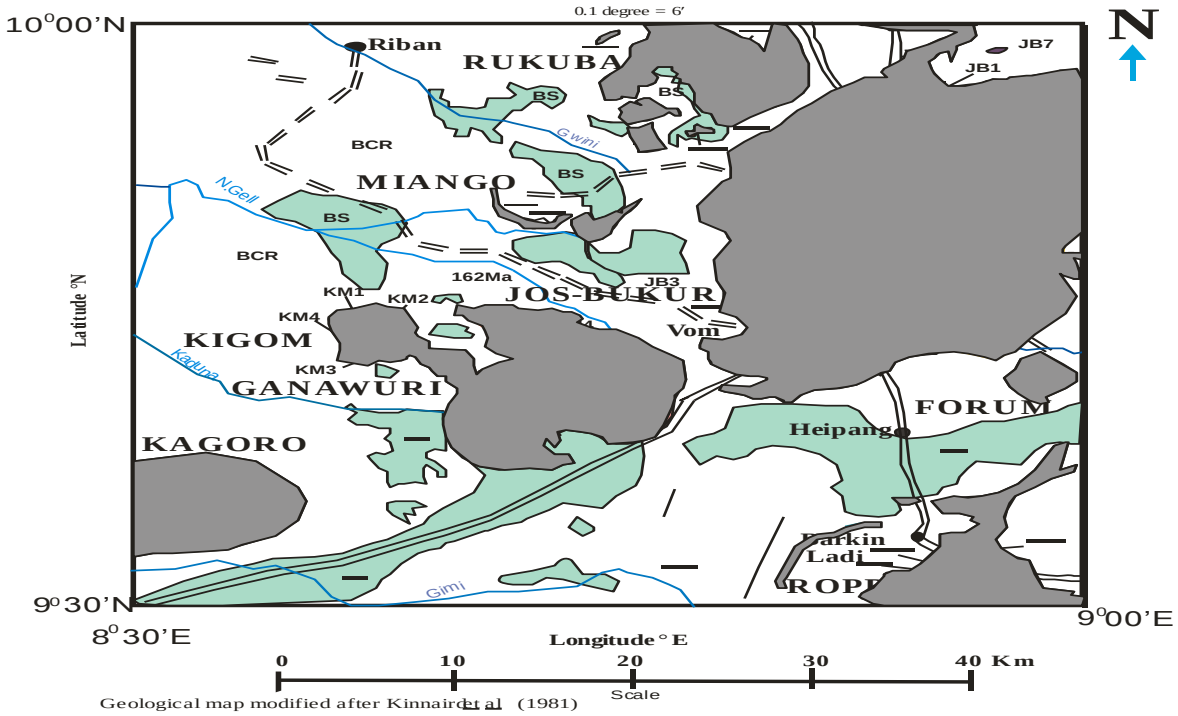
The aim of this study was to determine the gross alpha and beta activity concentration levels in ground water (boreholes and wells) in Tin mining areas of Plateau State, Central Nigeria, covered by the Naraguta Topographical sheet 168, Evaluation of radiation hazard indices and excess life time cancer risk.

Geology of the Study Area

Naraguta sheet 168 is underlain by three main classes of rocks. These include the basement complex, the younger Granites as well as the basalts. While the basement rocks found here are generally confined to the western and southern parts of the sheet the younger granites rocks are mainly found stretching from the south eastern to the northern parts of the area. The newer basalts are found mainly around the southern part with few pockets in the central and in the north basement rocks and the newer balts contain little or no radioactive mineralization the younger granites contain cassiterites.

The cassiterite is associated with columbite, monazite and trace amounts of xenotine (Okeyode and Akanni, 2009).

These minerals are therefore a major source of radioactivity in the groundwater and surface water in this area.



Geological map modified after Kinnaird et al (1981)

Figure 1 Geological map of the Naraguta Sheet 168.

Explanation

River/Stream
Major Road
Minor Road
Newer Basalt
Younger Granite
Basement Complex

Materials and Methods

Groundwater (boreholes and wells) samples from mining areas in Plateau State covering the Naraguta topographical sheet 168 were taken randomly.

The area is bounded between longitude $8^0 30^1$E to $9^0 00^1$E and latitude $9^0 30^1$N to $10^0 00$N as shown in fig 1.

Sample Collection and Preparation

Fifty eight (58) groundwater samples (23 borehole samples and 35 well samples) were collected randomly from the mining areas of Plateau State covered by the Naraguta Topo. Sheet 168. At each sampling point, two litres of the water samples were drawn in a two litre plastic container. The quantity of water collected was such that an air space of 1% of the container capacity was left for thermal expansion.

The samples were immediately acidified with nitric acid solution to reduce the Ptt, minimize precipitation and absorption by the walls of the container and to prevent the growth of micro-organisms. The sample containers were air tight and taken to the laboratory and held for atleast 24 hours before preparation.

The samples were evaporated using hot plates, without stirring and at moderate heat in an opened 600ml beaker. The evaporated samples were transferred into petri-dishes and placed under infrared light source to completely dry the residues. These were then transferred to planchets in the appropriate quantities according to ISO standard. A few drops of Vinyl acetate were dropped on the residues to make them stick to the planchets to prevent scattering during counting.

Counting

The gross alpha and beta activity counting in this study was carried out using a proportional counter (MPC – 2000 - Dp). The planchets containing the residues were placed in a sample carried which was placed in a sample drawer of the MPC – 2000 – Dp and slided into the system. Counting was done automatically according to the selected count mode when the appropriate sample information was entered.

The gross alpha and beta activity concentrations were calculated using the formula (ISO, 1992).

$$alpha\ activity\ concentration\ (Bq/l) = \frac{(R_0+R_0)\times m\times a_s\times 1.02}{1000(R_0-R_0)V} \quad (1)$$

$$Beta\ activity\ concentration\ (Bq/l) = \frac{(R_0-R_0)\ 14.4m(1.02)}{1000(R_s-R_0)V} \quad (2)$$

Where R_0 = sample count rate in pulse per second

R_s = observed count rate in pulse per second

R_0 = background planchet count rate in pulse per second

V = volume of sample in litres

m = mass of residue

a_s = specific activity of the standard solid in Bq/l

It is important that the factor 1.02 be included in the final equation to correct for the 20ml of the nitric acid added to the sample on a stabilizer.

Radiation Hazard Indices Calculation

Standard radiation hazard indices are used to evaluate the effects of radiation on the health of people exposed to radiation and the environment the indices to be evaluated are:

Annual Effective Dose Equivalent (AEDE)

The annual effective Dose Equivalent can be calculated using the equation (Marbaniang, 2011)

$$DR = A\ X\ IR\ X\ ID \quad (3)$$

DR = Effective Dose Equivalent

A = Activity (Bq/l)

IR = intake of water for a person in a year (730l)

ID = Ingestion dose equivalent factor (3.58 x 10^{-7}mSv/yr).

Annual Gonnadal Equivalent Dose (AGED)

The AGED is a measure of the threat and stomach from exposed to a particular level of radiation.

The AGED for members of the public for a given activity is given by (UNSCEAR, 1998).

$$AGED = \frac{AEDE}{Radiation\ Weighing\ Factor\ (W_e)\times tissues\ weighting\ factor\ (W_t)} \quad (4)$$

Where W_e for α – activity = 20

W_e for β – activity = 1

W_t for Gonads = 0.20

Excess Lifetime Cancer Risk (ELCR)

This deals with the probability of developing cancer over a lifetime at a given exposure level considering 70 years as the average duration of life for human beings. It is given by (Ajibola et al, 2013).

ELCR = AEDE = DL = RF (5)

Where AEDE = Annual Effective Dose Equivalent

DL = Average duration of life (estimated to be 70 years)

RF = Risk factor (SV^{-1}) for stochastic effects ICRP used RF as 0.05 for public.

RESULTS AND DISCUSSION

Tables 1 to 4 show the gross alpha/beta activity concentrations and the radiation hazard indices values in the study area. Figs 2 and 3 show the comparison distribution of Alpha and Beta annual effective dose equivalent in ground water with guideline standard.

Figs 4 and 5 show the comparison of the Annual Gonnadal Equivalent Dose for alpha and beta activity in the study area with the world standard value, Figs 6 and 7 show the Excess Life Cancer Risk compared with the standard value.

RESULTS

Table 1: Gross Alpha (α) Radiation Hazard Indices in Ground (Borehole) Water Supply in Jos Plateau State.

S/N	Location	Gross Alpha(α) activity (Bq/L)	Annual Effective Dose Equivalent (mSv/yr)	ELCR×10^{-3}	AGED (mSv/yr)
1	Ratatis (Dorowa)	0.430	0.112	0.392	0.028
2	Nafan Dredge	1.230	0.321	1.124	0.080
3	Gashan Gwol B/Ladi	0.540	0.141	0.494	0.035
4	Sho	0.770	0.201	0.704	0.050
5	Rahwol Gassa	0.260	0.068	0.238	0.017
6	Heipang (polytechnic)	0.140	0.037	0.130	0.009
7	Foron	0.110	0.029	0.102	0.007
8	Bisichi	0.110	0.029	0.102	0.007
9	Jantar Kuru	0.440	0.115	0.403	0.029
10	Marraba Jama'a	0.320	0.084	0.294	0.021
11	Rim	0.630	0.165	0.578	0.041
12	Hoss	0.190	0.050	0.175	0.013
13	Gana wuri	0.420	0.110	0.385	0.028
14	Angul Dee	0.280	0.073	0.256	0.018
15	Du	0.470	0.123	0.431	0.031
16	Mai Idon Taro	0.320	0.084	0.294	0.021
17	Sot-Gyel	1.580	0.413	1.446	0.103
18	Sabon Gida	1.540	0.403	1.411	0.101
19	Bingham University Teaching Hospital	0.200	0.052	0.182	0.013

20	Gada Biyu Jos	0.620	0.162	0.567	0.041
21	Yan Trailer	0.690	0.180	0.630	0.045
22	Juth	1.160	0.303	1.061	0.076
23	New life for all Hqtrs	1.320	0.345	1.208	0.086

Table 2: Gross Beta (β) Radiation Hazard Indices in Ground (Borehole) Water Supply in Jos Plateau State.

S/N	Location	Gross Beta(β) activity (Bq/L)	Annual Effective Dose Equivalent (mSv/yr)	ELCR×10^{-3}	AGED (mSv/yr)
1	Ratatis(Dorowa)	0.240	0.063	0.221	0.315
2	Nafan Dredge	1.090	0.285	0.998	1.425
3	Gashan Gwol B/Ladi	0.350	0.092	0.322	0.460
4	Sho	0.160	0.042	0.147	0.210
5	Rahwol Gassa	0.050	0.013	0.046	0.065
6	Heipang (polytechnic)	0.040	0.011	0.039	0.055
7	Foron	0.060	0.016	0.056	0.080
8	Bisichi	0.040	0.011	0.039	0.055
9	Jantar Kuru	0.100	0.026	0.091	0.130
10	Marraba Jama'a	0.170	0.044	0.154	0.220
11	Rim	0.014	0.004	0.014	0.020
12	Hoss	0.070	0.018	0.063	0.090
13	Ganawuri	0.170	0.044	0.154	0.220
14	Angul Dee	0.060	0.016	0.056	0.080
15	Du	0.190	0.050	0.175	0.250
16	Mai Idon Taro	0.012	0.003	0.011	0.015
17	Sot-Gyel	1.600	0.418	1.463	2.090
18	Sabon Gida	1.070	0.280	0.980	1.400
19	Bingham University Teaching Hospital	0.870	0.227	0.795	1.135
20	Gada Biyu Jos	0.920	0.240	0.840	1.200
21	Yan Trailer	0.580	0.152	0.532	0.760
22	Juth	1.130	0.295	1.022	1.475
23	New life for all Hqtrs	2.760	0.721	2.524	3.605

Table 3: Gross Alpha (α) Radiation Hazard Indices in Ground (Well) Water Supply in Jos Plateau State.

S/N	Location	Gross Alpha(α) activity (Bq/L)	Annual Effective Dose Equivalent (mSv/yr)	ELCR×10^{-3}	AGED (mSv/yr)
1	Ratatis(Dorowa)	1.840	0.481	1.684	0.120
2	Nafan Dredge	0.410	0.107	0.375	0.027
3	B/Ladi (Katako)	0.440	0.115	0.403	0.029
4	Sho	0.220	0.006	0.021	0.002
5	Rahwo Gassa	0.500	0.131	0.459	0.033
6	Nding	0.670	0.175	0.613	0.044
7	Heipang	0.870	0.227	0.795	0.057
8	Foron Zabot	12.590	3.290	11.515	0.823
9	Bisichi	0.370	0.097	0.340	0.024
10	Jantar Kuru	0.440	0.115	0.403	0.029
11	Science School Kuru	0.810	0.212	0.742	0.053
12	Marraba Jama'a	0.130	0.034	0.119	0.009
13	Ganawuri	0.010	0.003	0.011	0.001
14	Bum	0.021	0.006	0.021	0.002
15	Rim	0.150	0.392	1.372	0.098
16	Vom	0.260	0.068	0.238	0.017
17	Angul Dee	0.160	0.418	1.463	0.105
18	Angul Dee II	7.710	2.015	7.053	0.504
19	Zawan	0.570	0.149	0.522	0.037
20	Du	1.450	0.379	1.327	0.095
21	Mai Idon Taro	0.280	0.073	0.256	0.018
22	Sot-Gyel	0.860	0.225	0.788	0.056
23	Sabon Gidan Kanar	0.190	0.050	0.175	0.013
24	Federal Secretariat	0.270	0.071	0.249	0.018
25	Tudun Wada	0.580	0.152	0.532	0.038
26	Jenta	1.810	0.473	1.656	0.118
27	St Murumba College	0.580	0.152	0.532	0.038
28	Student Village	1.410	0.369	1.292	0.092
29	Bauchi Junction	0.460	0.120	0.420	0.030
30	Old Police Barrack	1.420	0.371	1.299	0.093
31	Nassarawa Gwong	0.450	0.118	0.413	0.030
32	Fudawa	2.820	0.737	2.580	0.184
33	Furaka	0.320	0.084	0.294	0.021
34	Dogon Karfe	0.260	0.068	0.238	0.017
35	Abattoir	0.910	0.238	0.833	0.060

Table 4: Gross Beta (β) Radiation Hazard Indices in Ground (Well) Water Supply in Jos Plateau State.

S/N	Location	GrossBeta(β) activity (Bq/L)	Annual Effective Dose Equivalent (mSv/yr)	ELCR×10^{-3}	AGED (mSv/yr)
1	Ratatis(Dorowa)	1.540	0.403	1.411	2.015
2	Nafan Dredge	0.180	0.047	0.165	0.235
3	B/Ladi (Katako)	0.020	0.005	0.018	0.025
4	Sho	0.110	0.003	0.011	0.015
5	Rahwol Gassa	0.030	0.078	0.273	0.390
6	Nding	0.100	0.026	0.091	0.130
7	Heipang	0.280	0.073	0.256	0.365
8	Foron Zabot	14.640	3.830	13.405	19.150
9	Bisichi	0.090	0.024	0.084	0.120
10	Jantar Kuru	0.160	0.042	0.147	0.210
11	Science School Kuru	0.170	0.044	0.154	0.220
12	Marraba Jama'a	0.040	0.011	0.039	0.055
13	Ganawuri	0.070	0.183	0.641	0.915
14	Bum	0.270	0.071	0.249	0.355
15	Rim	0.040	0.011	0.039	0.055
16	Vom	0.130	0.034	0.119	0.170
17	Angul Dee	0.040	0.011	0.039	0.055
18	Angul Dee II	7.220	1.890	6.615	9.450
19	Zawan	0.440	0.115	0.403	0.575
20	Du	0.040	0.011	0.039	0.055
21	Mai Idon Taro	0.110	0.029	0.102	0.145
22	Sot-Gyel	0.600	0.157	0.550	0.785
23	Sabon Gidan Kanar	0.040	0.011	0.039	0.055
24	Federal Secretariat	0.760	0.199	0.697	0.995
25	Tudun Wada	1.540	0.403	1.411	2.015
26	Jenta	5.400	1.411	4.939	7.055
27	St Murumba College	1.220	0.319	1.117	1.595
28	Student Village	2.470	0.646	2.261	3.230
29	Bauchi Junction	1.070	0.280	0.980	1.400
30	Old Police Barrack	3.000	0.784	2.744	3.920
31	Nassarawa Gwong	1.320	0.345	1.208	1.725
32	Fudawa	5.200	1.359	4.757	6.795
33	Furaka	0.980	0.256	0.896	1.280

34	Dogon Karfe	0.740	0.193	0.676	0.965
35	Abattoir	1.700	0.444	1.554	2.220

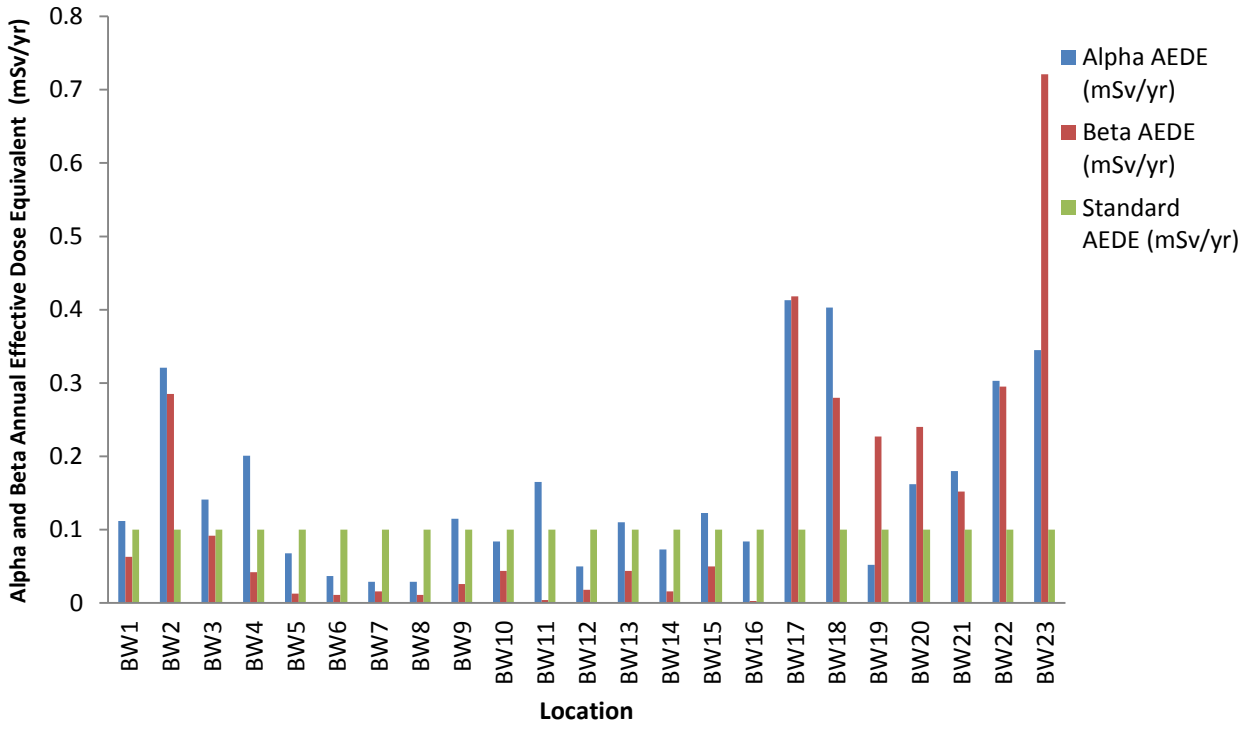


Fig 2: Annual Effective Dose Equivalent Distribution for Alpha and Beta Activity in Borehole Water (BW) Sample

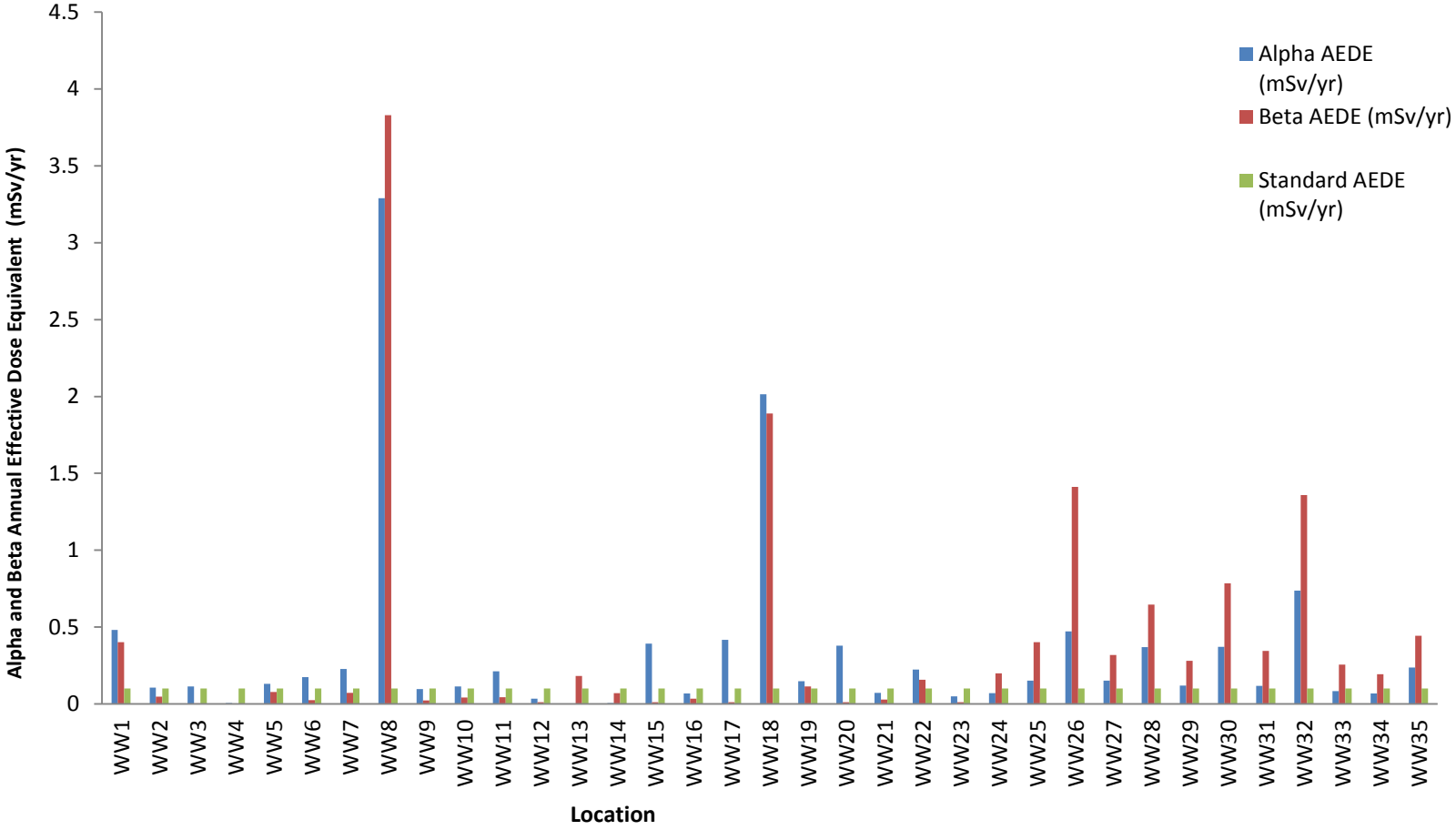


Fig 3: Annual Effective Dose Equivalent Distribution for Alpha and Beta Activity in Well Water (WW) Samples

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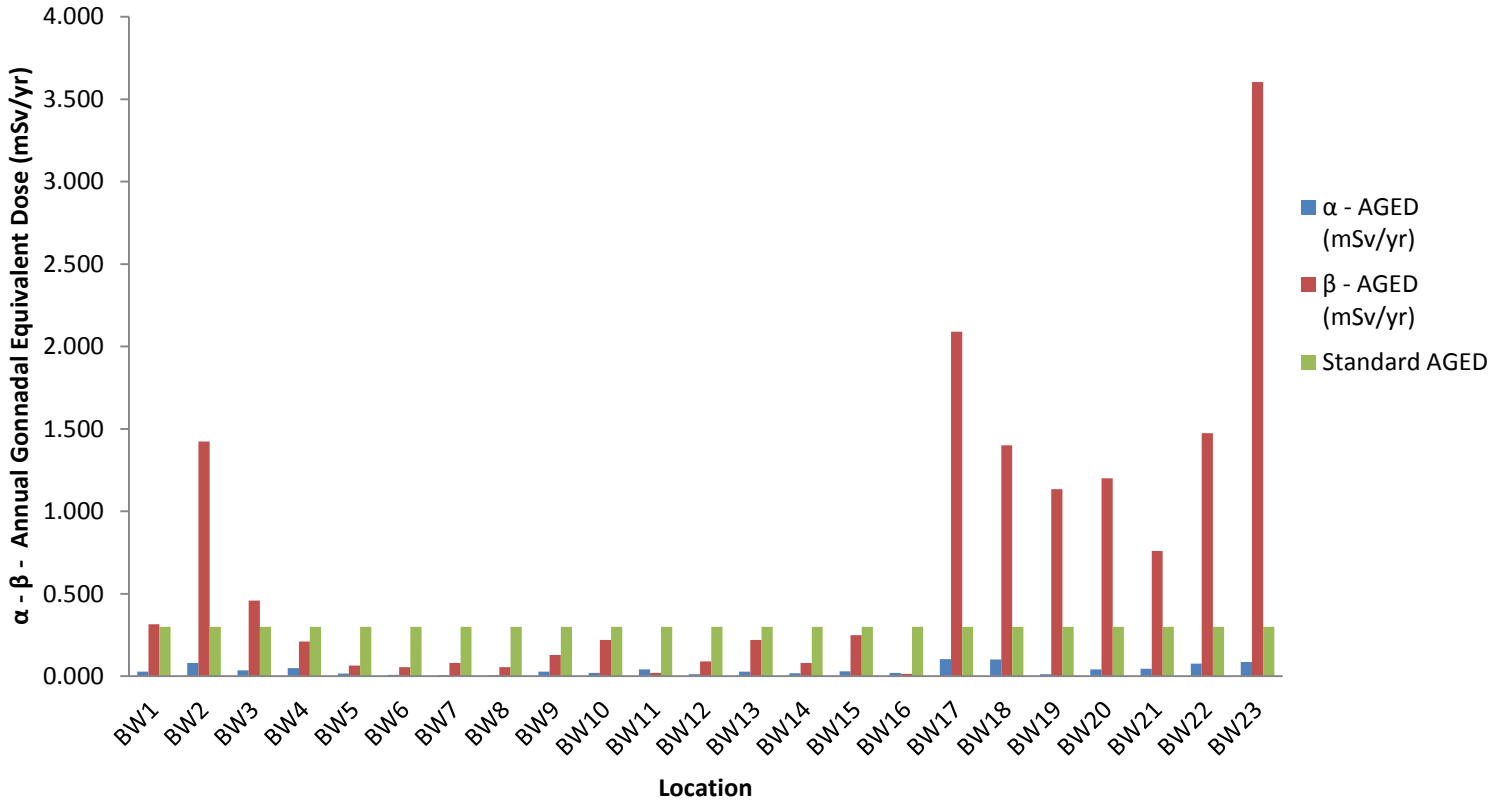

Fig 4: Annual Gonnadal Equivalent Dose for Alpha and Beta Activity in Borehole Water (BW) Samples

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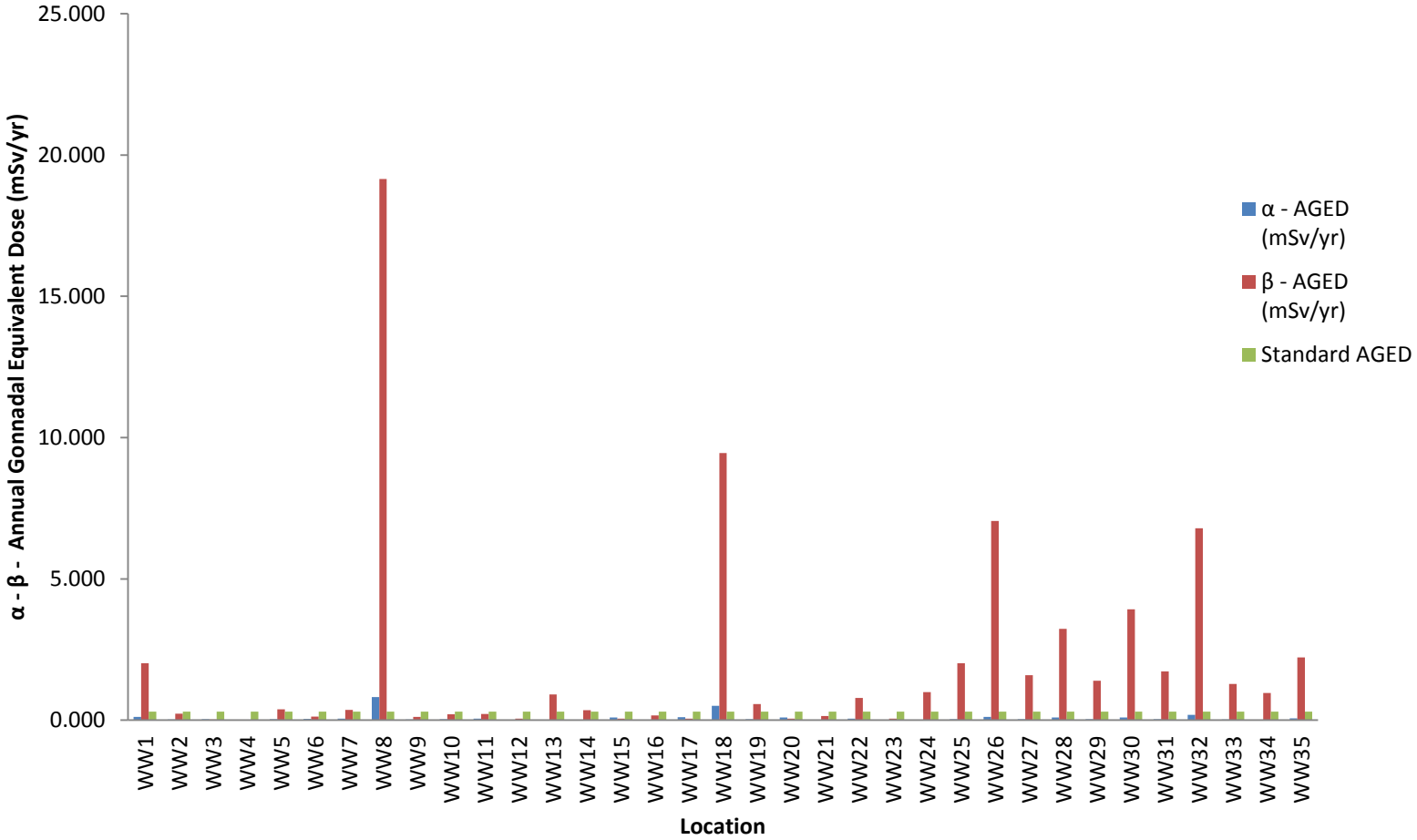

Fig 5: Annual Gonnadal Equivalent Dose for Alpha and Beta Activity in Well Water (WW) Samples

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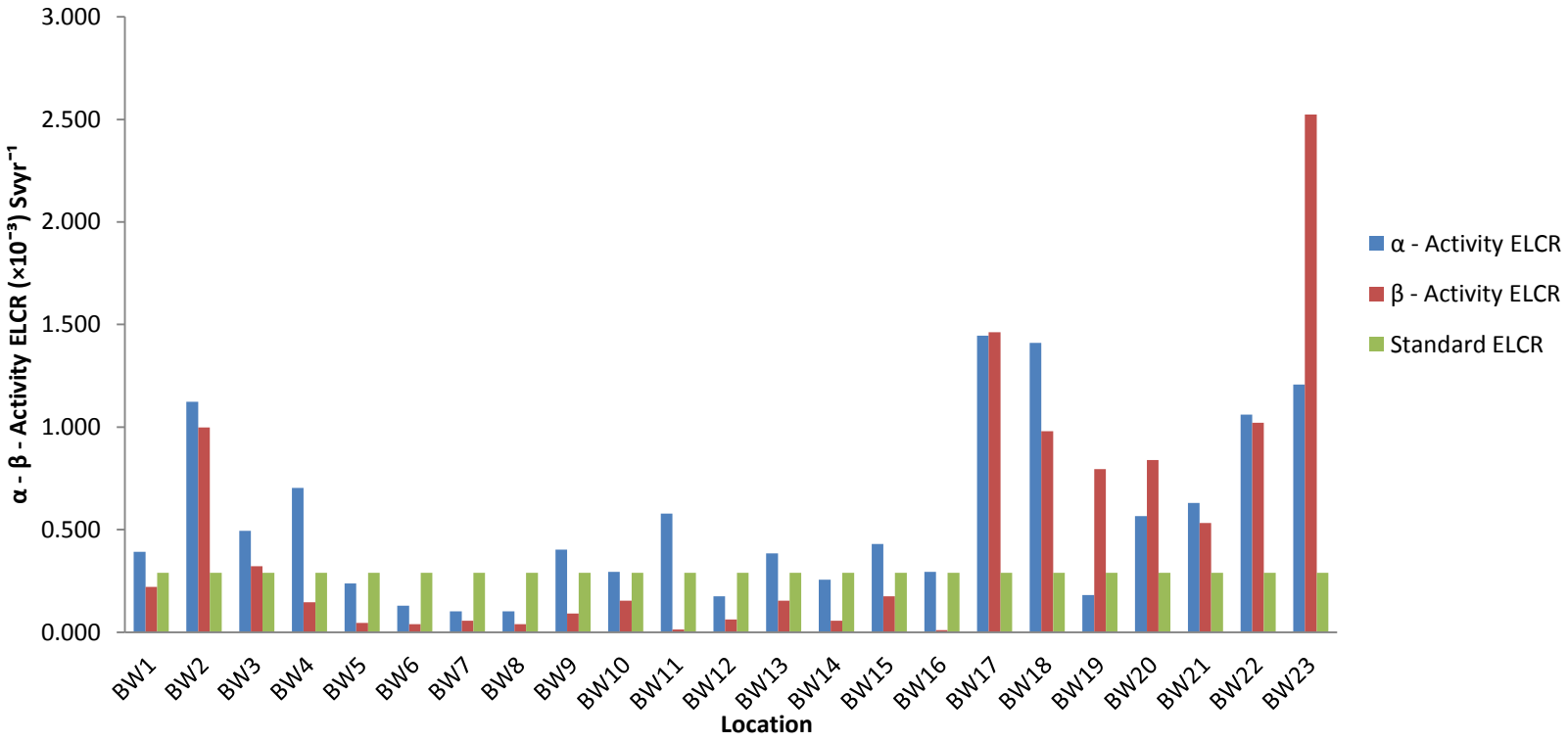

Fig 6: Excess Lifetime Cancer Risk for Alpha and Beta Activity in Borehole Water (BW) Samples

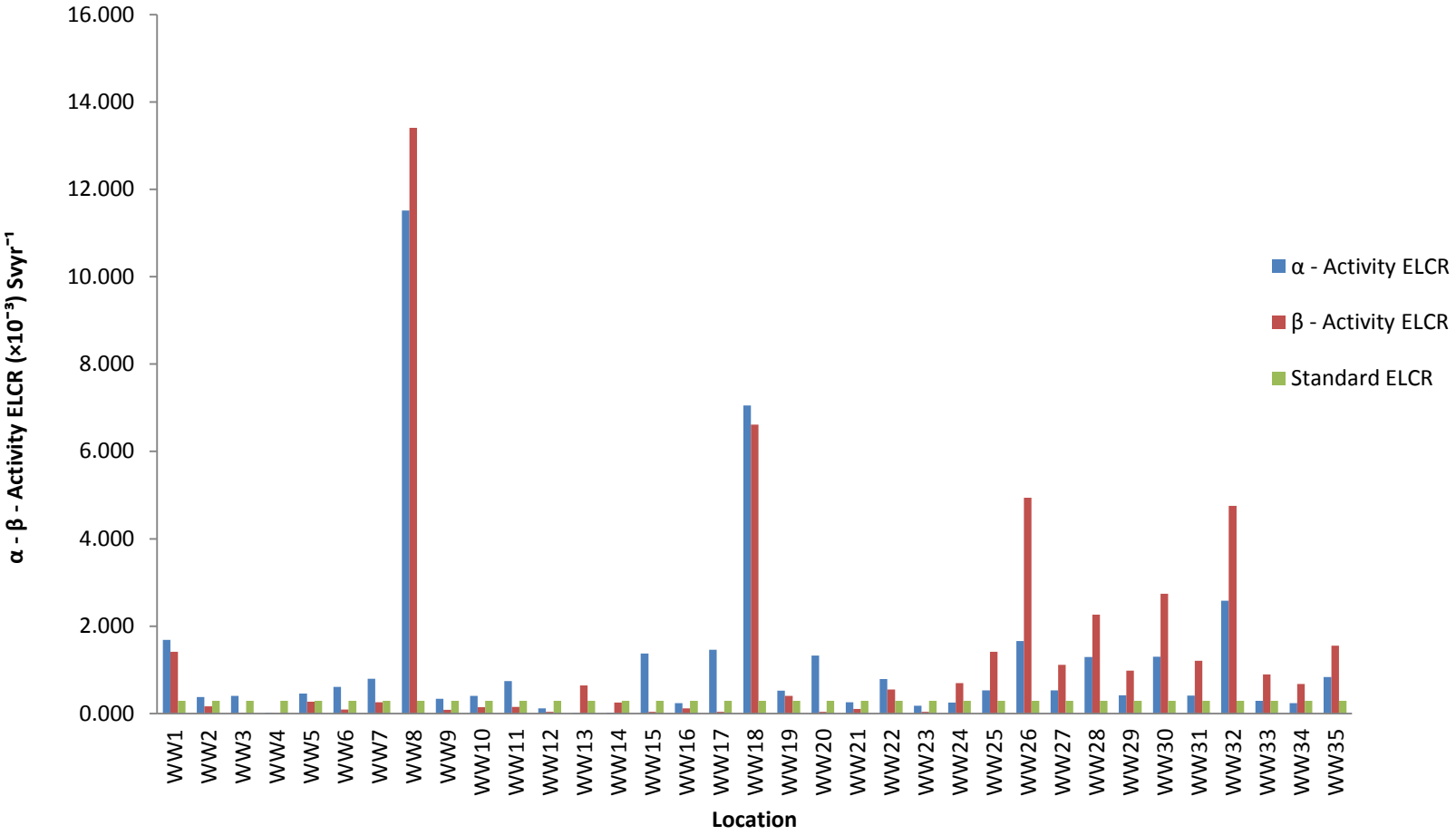

Fig 7: Excess Lifetime Cancer Risk for Alpha and Beta Activity in Well Water (WW)

DISCUSSION

Tables 1 and 2 show that the highest gross alpha and beta activity concentrations in borehole samples are above the WHO guideline value of 0.5Bq/l (WHO, 2008). The results obtained for Annual Effective Dose Equivalent for both alpha and beta emitting radionuclides in borehole samples show most locations above the recommended limits of 0.1mSv/yr (WHO, 2008). For annual gonadal dose equivalent, the results are below the permissible level of 300mSv/yr (UNSCEAR, 2000). However most of the values of the excess lifetime cancer risk are above the world average value of 0.29 x 10^{-3} (Taskin et al, 2009). Tables 3 and 4 display the results in well water samples that show general elevated values of gross alpha and beta, AEDE, AGED and ELCR foremost of the locations. This signifies that there is a radiological burden on the people and the environment of these areas and there is the possibility of one out of a thousand developing cancer before 70 years by the local miners and those living in the areas.

CONCLUSION

The gross alpha and beta activity concentrations levels, evaluation of radiation hazard indices and excess lifetime cancer risk of groundwater sources in the mining areas of Plateau State Nigeria have been conducted.

The values obtained when compared with the various world standards values were below the standards in some few locations but above in most locations. This will pose significant health threat to human lives and the environment.

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REFERENCES

1. **Ajibode M.O., Avwiri G.O., and Agbalagba, E. O. (2013): Evaluation of Radiation Hazard Indices in an Oil Mineral Lease (Oil Block) in Delta State, Nigeria. International. Journal of Engineering and Applied Sciences. Vol. 4. No 2.pp. 104 – 121**
2. **Eric J, Nguelem, M, Danko E.O, Ndontchueng M. M., Schandorf, C. Akiti T. T. , Muhulo, A. P. and Bam E. K. P.,(2013). The Natural Radioactivity in Ground Water from Selected areas in Greater Accra Beta Measurements. Radiation Protection and Environment: Vol: 36, Issue 1: 14 – 19.**
3. **International Organization of Standardization (1992). Water Quantity Measurement for Gross Alpha and Beta Activity in Non-Saline Water, thick Source Method, ISO (9696 – 1992 revised) and ISO (9697 – 1992 revised). Geneva, Switzerland. 13p.**
4. **Karahan G., Ozturk N., and Ahmet B. (2000). Natural Radioactivity in various Surface Waters in Istanbul, Turkey. Water Resources: 24: 4367 – 70.**
5. **Kinnaird, J.A., Bowden, P., Bennett, J. N., Turner, D.C., Ike E. E., Abba, S.L., Moyes, A.B., Badejoko, T.A.,Weir, J., Martin, R.F. and Barrlere, M. (1981). Geology of the Nigerian Anarogenic Ring Complex. Town Bartholomew and Sons Ltd. Uk.**
6. **Marbaniang, D. G. (2011). Radioactivity (Gross alpha and Gross beta) studies of Surface Water Collected from Domiasiat Area, west Khasi Hills District Meghalaya India. International Journal of Environmental Protection, 1(4), Pp 17 – 21.**
7. **Okeyode I. C., and Akanni A. O. (2009). Determination of some Physical Parameters of Olumorocks, Abeokuta, Ogun State Nigeria. Indian Journal of Science and Technology Vol. 2. No. 7. Pp 6 – 10.**
8. **Pujol Li and Sanechez-Cebeza, J.A (2000). Natural and and Artificial Radioactivity in Surface waters of the Ebro River Basin (Northeast Spain). Journal of Environ, Radioactivity; 51: 181 – 210.**
9. **Solomon, A. O. (2005). A study of Natural Radiation levels and Distribution of Dose rates Within the Younger Granites Province of Nigeria. A Ph.D Thesis, University of Jos, Nigeria.**
10. **Taskin, H.M., Karavus, P., $A_{y,}$ A., Touzogh, S., Hindirogglu and Karaliam, G. (2009). Radionuclides Concentration**

in Soil and Life time Cancer Risk Due to gamma Radioactivity in Kirk/ardi, Turkey. Journal of Environmental Radioactivity, 100. 49 – 53.

11. UNSCEAR (2000): United Nation Scientific Committee on the Effects of Atomic Effects of Ionizing Radiation, New York.
12. WHO (1998). Guidelines for Drinking Water Quality. 2nd Edition Addendum to Volume 2: Health Criteria and Other Supporting Information, WHO/EDS/98. Geneva, Switzerland, Pp. 283.
13. WHO (2008). Guidelines for Drinking Water 3rd Edition, Incorporating the First and Second Addendum Vol.1. Recommendations, Geneva.