

Gross Alpha and Beta Radio Activity Concentrations and Estimated Committed Effective dose to the General Public Due to Intake of Groundwater in Mining Areas of Plateau State, North Central Nigeria

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Abstract
Tin mining activities carried out in parts of plateau state from the beginning of this century to the early 1980's have left behind a post mining environment scarred by numerous mine pond and uncontrolled heaps of mine tailings containing radioactive minerals that have found their way into the natural water resources. In this study the gross activities of the alpha and beta emitting radionuclides present in the naturally occurring water bodies in the mining areas of plateau state covered by Naraguta sheet 168 were determined. Fifty-eight (58) groundwater, comprising of twenty-three (23) borehole and thirty-five (35) locally dug well samples were drawn randomly. The samples were analyzed and counted for gross alpha and beta activities using MPC-2000-DP. The results showed that the range of alpha activity varied from (0.110-1.580)Bq/l with a geometric mean of 0.328 Bq/l for borehole samples and (0.010-12.590)Bq/l with a geometric mean of 0.498 Bq/l for well water samples. The range of beta activity varied from (0.012-2.760) Bq/l with a geometric mean of 0.198 Bq/l for borehole water samples and (0.020-14.640) with the geometric mean of 0.366Bq/l for well water samples. Most of the samples show higher concentration above the WHO guideline value of 0.5Bq/l for alpha activity and 1.0Bq/l for beta activity. The annual committed effective (CED) to infants, children and adults were estimated. The results shared elevated values in most of the location above the ICRP acceptable standard of 0.1mSv/yr. The mean values of CED due to intake of borehole water for alpha activity are 0.240mSv/yr, 0.481mSv/yr and 0.885mSv/yr for infants, children and adult respectively. For beta activity the values are 0.201mSv/yr, 0.410 mSv/yr. and 0.820 mSv/yr. In the well water samples the mean CED value for alpha activity are 0.485 mSv/yr, 0.963 mSv/yr. and 1.938mSv/yr for infants, children and adults respectively and for beta activity the mean values are 0.594 mSv/yr., 1.187mSv/yr. and 2.375 mSv/yr. respectively. These values show that the general public in these locations are committed to higher dose above the standard values and long term exposure could pose health threat.
Keywords: Gross alpha, gross beta, Mine tailings, water, Radionuclides

1. Introduction

Water is important and necessary for life. All living organisms need water; same live in it and same drink it. Water is useful to humans for drinking, as a solvent, as a thermal transferagent, for domestic and recreational purposes, food processing, power generation and agriculture. Water has to be skillfully managed if it is to be used for these diverse purposes.

Plants and animals require water that is moderately pure and they cannot survive if the water is loaded with toxic chemicals or harmful micro-organisms. In nature however, water washes gases from atmosphere, dissolve minerals and soluble substances from the soil through which it flows. As such many contaminants and micro-organisms enter into it thereby polluting the water.

Polluted water or contaminated water is therefore defined as any water whose qualityhas been significant degraded (WHO, 1998). Water pollution like other environmental concerns has been the focus of widespread public interest for decades and this interest is increasing day-by-day (Abel, 1996). Water is polluted by the waste of civilization which enters water bodies through the discharge of water borne wastes. The same water could be used by the urban population for drinking and other domestic uses (Welch, 1992). Other wastes like industrial wastes, pulping wastes, petroleum and refinery wastes, food processing wastes, mining wastes and agricultural wastes often contain some amount of pollutants as a result of the materials used in generating the wastes therebyadding to the level of water pollution if they enter the water bodies. Water can pick radioactivity materials as it flows through rocks soli or cracked cement surrounding a water source, therebycontaminating the water sources (USEPA, 1996).

Groundwater could be contaminated by radioactive materials because terrestrial radioactivity increases with depth in the earth crust (WHO, 1998).These radioactive materials occur naturally and of most concern are the uranium and thorium series and the progenies (radon and thoron). They contribute to the radioactivity of the rain and groundwater which in turn affects drinking water. Due to these, drinking water from deep wells and boreholes are expected to contain high concentrations of radioactive elements. Radioactive materials could also be washed into wells, boreholes and even enter through burst pipes.Important radioactive elements in drinking water are tritium, potassium -40, radium and radon which are alpha or beta emitters (Surbeck, 1995).People who ingest polluted water candevelop illness and with prolonged exposure to radioactive polluted water can cause cancers, toxicity of the kidneys or bear children with birth defects (WHO, 2006).

Knowledge of the natural occurring radionuclide present in drinking water enables one to assess any possible radiological hazards to humans by the use of such water. Hence the objective of this research is to determine the gross alpha and beta radioactivity concentration in groundwater in the mining areas of plateau state and to estimate the committed effective dose to the different age brackets in the area. This study will also ascertain the safety of drinking water both borehole and well water source from the study area.

2. Geology of the Study Area

The geology of Nigeria can simply be grouped into the crystaline basement rocks and sedimentary formations, each constituting nearly of equal proportion. Granite rocks dominate the cyrstaline basement and two distinct groups of granites, which differ considerably in age, structure and mode of origin, have been recognized as older granites and younger granites. The older granites are a suite of syn-and late tectonic granites, diorites and granidiorites that marked the intrusive phase of the late Pan African Orogency dated 620 $\pm$ 10 Ma (McCurry, 1989). The younger granites are discordant, high level of magmatic intrusions with strong alkaline affinities that cut the basement rocks. They are Jurassic in age and occurs as ring-structures with a common sequence of an early volcanic phase followed by series of granite intrusion as observed by Funtua et al, (2004). The Jos Plateau is the centre of the younger granite and is dated 164 $\pm$ 4Ma (Rahaman, 1988). The rocks are predominantly SIO_2 – saturated,consisting of granites and rhyolites (> 90 vol. %), accompanied by quartz bearing syenites, gabbros and dolerites.

3. Materials and Methods

Experimental Design

The field data collection was carried out in the month of March and April and it lasted for about two weeks. The period was chosen because it represents the peak of the dry season in the study area. This is also the time when water qualify determination is critical; no flow of one source into another and good accessibility is enhanced. Groundwater (Borehole and wall) samples from mining areas in Plateau state covering Naraguta Topographical sheet 168 were collected. The area is bounded between Longitude $8^0$31'00.00” E to $8^0$59’00.00” E and Latitude $9^0$34’00.00”N to $9^0$55’00.00”Nasshown in Fig.1. Results for twenty-three (23) borehole samples and thirty-five (35) well water samples from different sampling points are presented in this study.

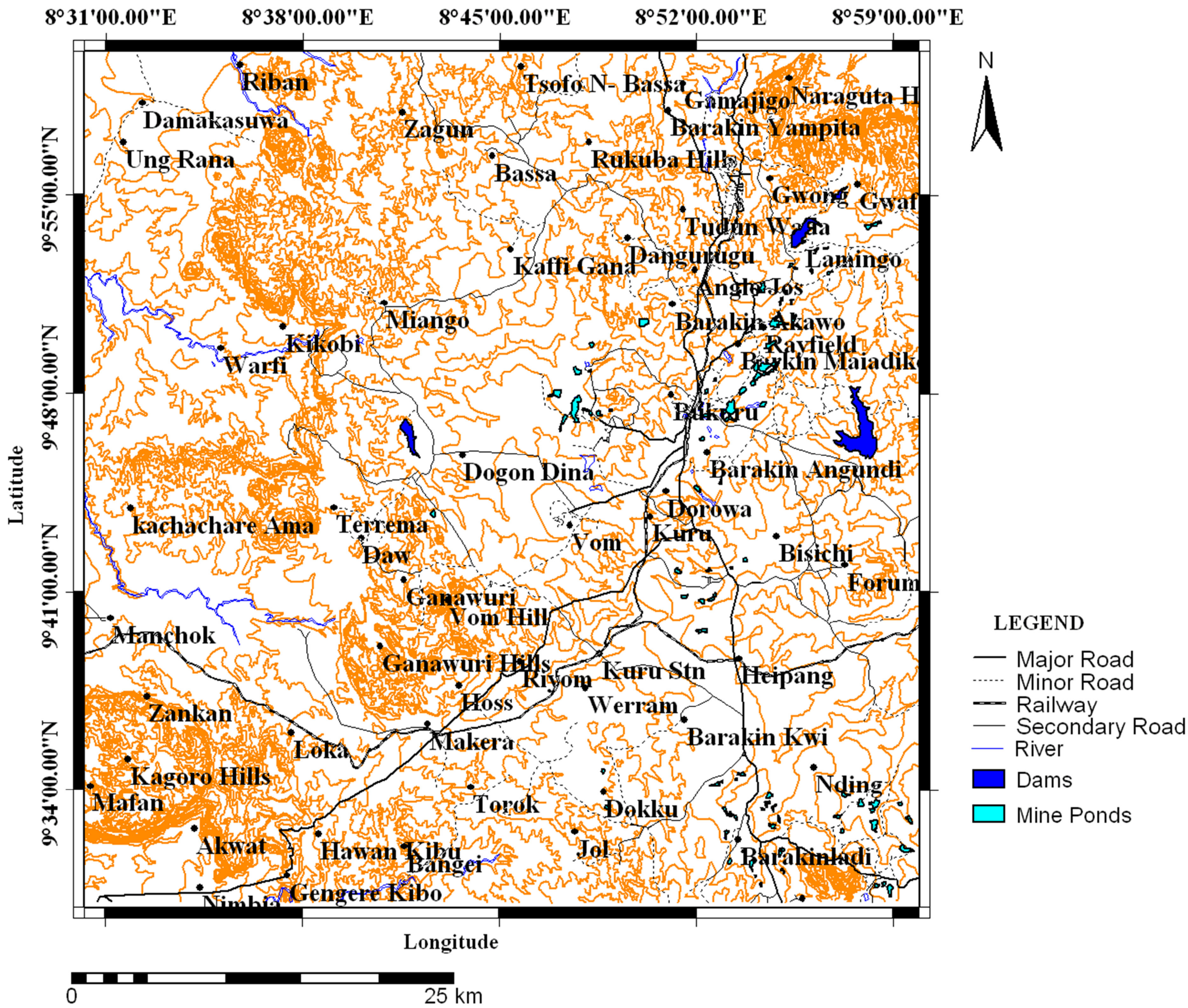

Fig 1: Naraguta Topographical sheet 168 (9°30' N to 10°00' N and8°30' E to 9°00' E)

3.1. Sample Collection and Preparation.

Fifty eight (58) water samples consisting of twenty three (23) borehole water samples and thirty –five (35) well water samples were collected from the mining areas of plateau state covered by the Naraguta sheet 168, from each sampling point, two liters of the water samples were drawn from each borehole and well source in a two (2) liters plastic container which was rinsed twice with the water sample and immediately acidified after collection with nitric acid solution to reduce the pH, minimized precipitation and absorption by the walls of the container and to prevent the growth of micro-organisms. The amount of water collected was such that an air space of 1% of the container capacity was left for thermal expansion. The samples were air tight. The samples were taken to the laboratory and held for at least 24hours before analysis. The samples maximum holding time before evaporation was one month and after evaporation was one month and after evaporation, residues were kept in the desiccator until they were ready for counting. Evaporation was done using hot plates, without stirring and at moderate heat in an open 600ml beaker. It took an average of about 16hrs to complete the evaporation of one liter of each sample. In the process of evaporation, when the level of sample in the beaker was about 50ml, it was then transferred into a petri-dish and placed under infrared light source to completely dry the residue. It was then allowed to cool before weighing was done. 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 planchet was weighed after which about 0.077g of the residue was transferred to the planchet (ISO-STANDARD). The planchet plus residue was then weighted. A few drops of Vinyl acetate were put on the sample to make them stick to the planchet to prevent scattering of the residue during counting. Sample preparation efficiency was obtained from the relation:

$$\frac{weight\ of\ residue\ transfered\ to\ planchet \times 100\%}{0.077g} \qquad (1)$$

Volume of water that gave the total residue was obtained from the relationship

$$v = \frac{V_w}{TR \times RP} \quad (2)$$

V_w = Volume of water = 1 litre ,TR = total residue
RP = residue transferred to Planchet.

3.2. Counting

The gross alpha and beta counting equipment used in this work was the MPC – 2000, a low background alpha and beta detector. The equipment is a non-gas proportional counter with an ultra thin window.
For the gross alpha and beta counting, the sample was placed in a planchet and the planchet containing the sample was placed in a sample carrier. The carrier was then placed on the sample drawer and closed. Counting was done automatically according to the selected count mode when the appropriate sample information was entered. The activity concentration (C) in Becquerels per Litre was calculated using the expression

$$C = R_n \times \frac{1}{\epsilon_s} \times \frac{1}{V_p} \quad (3)$$

Where C= activity in Becquerel per Litre, R_n = Sample count rate per second, corrected for background count, ϵ_s = fractional efficiency of counting the radioactive standard V_p= the volume of sample in litres equivalent to the mass on the planchet.
Thus $R_n = R_b - R_0$
R_b = the observed sample count rate, in pulses per second
R_0 = the background planchet count rate, in pulses per second

$$\epsilon_s = \frac{R_s - R_0}{0.1A \times 14.4} \times 1000 \quad (4)$$

Where
R_s = the observed standard rate in pulses per second
A = the area of the planchet, in square millimeters.

3.3. Estimation of Committed Effective Dose

The committed effective dose to an individual due to intake of alpha/beta emitting radionuclides from all the water samples over one year was estimated using the relation (Onoja, 2011).

$$CED = A \times IW \times DCF \quad (5)$$

Where A = sample activity concentration (Bq/L)
IW = water intake
For an infant ($\leq 1yr$) in a year is 182.5L
For a child (1-12yrs) in a year is 365L
For teenagers/adults (>12yrs) in a year (730L)
DCF = Dose Conversion Factor (mSv/Bq)
Dose Conversion Factor used to calculate the internal exposure by ingestion of radionuclides of radionuclides of radiological significance in drinking water for members of the public is 2.2 x10^{-3} mSv/Bq (DMP, 2010).

4. Results

Table 1: Gross Alpha and Beta Radioactivity Concentration (Bq/L) of Borehole water Samples Collected in Mining Areas in Plateau State.

				α - Annual Committed Equivalent Dose (mSv yr-1)			β - Annual Committed Equivalent Dose (mSvyr-1)		
Sample ID	**Sample Location**	**Alpha(α) Activity (Bq/L)**	**Beta(β) Activity (Bq/L)**	**infant ≤ 1yr**	**Children 1-12yrs**	**Teenager/Adult ≥12**	**infant ≤ 1yr**	**Children 1-12yrs**	**Teenager/ Adult ≥12**
BW 01	Ratatis (Dorowa)	0.430±0.009	0.240±0.008	0.173	0.345	0.691	0.01	0.193	0.385
BW 02	Nafan –Dredge	1.230±0.017	1.090±0.020	0.494	0.988	1.975	0.438	0.875	1.751
BW 03	Barkin ladi Gashan – Gwol	0.540±0.019	0.350±0.001	0.217	0.434	0.867	0.141	0.281	0.562
BW 04	Sho	0.770±0.012	0.160±0.010	0.309	0.618	1.237	0.064	0.128	0.257
BW 05	Rahwol Gassa	0.260±0.013	0.050±0.011	0.104	0.209	0.418	0.02	0.04	0.08
BW 06	Heipang (Polytechnic)	0.140±0.011	0.040±0.001	0.056	0.112	0.225	0.016	0.032	0.064
BW 07	Foron	0.110±0.010	0.060±0.001	0.044	0.088	0.177	0.024	0.048	0.096
BW 08	Bisichi	0.110±0.010	0.040±0.001	0.044	0.088	0.177	0.016	0.032	0.064
BW 09	Jantar Kuru	0.440±0.013	0.100±0.011	0.177	0.353	0.707	0.04	0.08	0.161
BW 10	Maraba Jama'a	0.32±0.009	0.170±0.010	0.128	0.257	0.514	0.068	0.137	0.273
BW 11	Rim (Ang.Reng)	0.63±0.012	0.014±0.007	0.253	0.506	1.012	0.006	0.011	0.023
BW 12	Hoss	0.190±0.010	0.070±0.001	0.076	0.153	0.305	0.028	0.056	0.112
BW 13	Ganawuri	0.420±0.013	0.170±0.012	0.169	0.337	0.675	0.068	0.137	0.273
BW 14	Angul DEE	0.280±0.013	0.060±0.011	0.112	0.225	0.45	0.024	0.048	0.096
BW 15	DU	0.470±0.017	0.190±0.014	0.189	0.377	0.755	0.076	0.153	0.305
BW16	Mai-idon –Taro	0.320±0.012	0.012±0.013	0.128	0.257	0.513	0.005	0.01	0.019
BW 17	Sot-Gyel	1.580±0.014	1.600±0.013	0.634	1.269	2.538	0.642	1.285	2.57
BW 18	Sabon Gidan Kanar	1.540±0.018	1.070±0.019	0.618	1.237	2.473	0.43	0.859	1.718
BW 19	Bingham university Teaching Hospital	0.200±0.040	0.870±0.070	0.08	0.161	0.321	0.349	0.699	1.397
BW 20	Gada Biyu, Jos	0.620±0.060	0.920±0.080	0.249	0.498	0.1	0.369	0.739	1.478
BW 21	Yan Trailer	0.690±0.060	0.580±0.010	0.277	0.554	0.233	0.233	0.466	0.932
BW 22	JUTH	1.160±0.012	1.130±0.011	0.466	0.931	1.863	0.454	0.908	1.815
BW23	New life for all Hqtrs	1.320±0.016	2.760±0.026	0.53	1.06	2.12	1.108	2.216	4.433

BW: Borehole Water

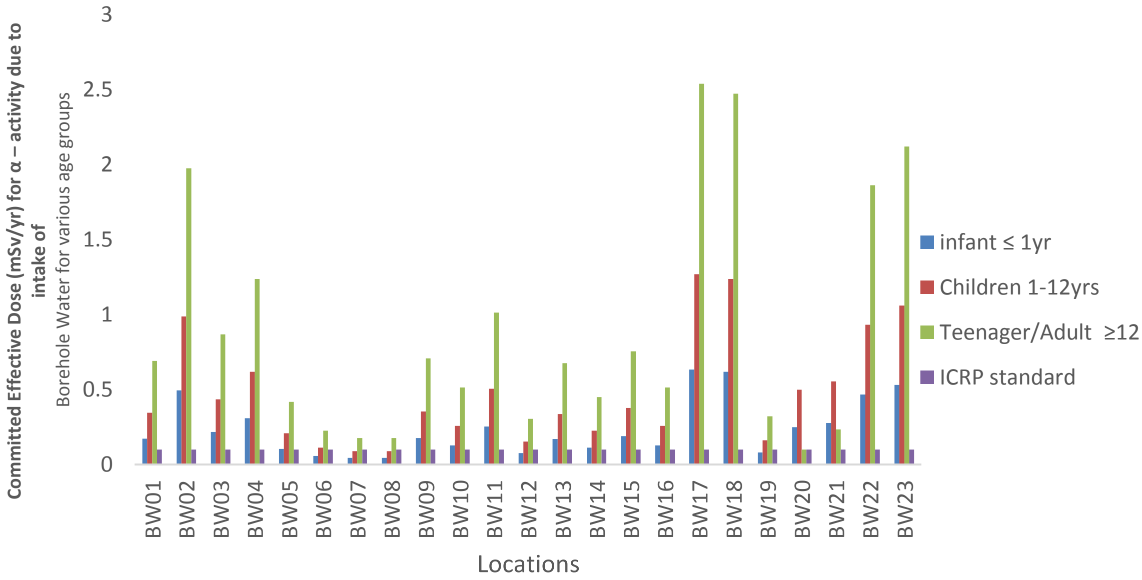

Fig 2: Comparison of Committed Effective Close for Different Age Groups Due To Alpha Radioactivity in Borehole Water with ICRP Standard.

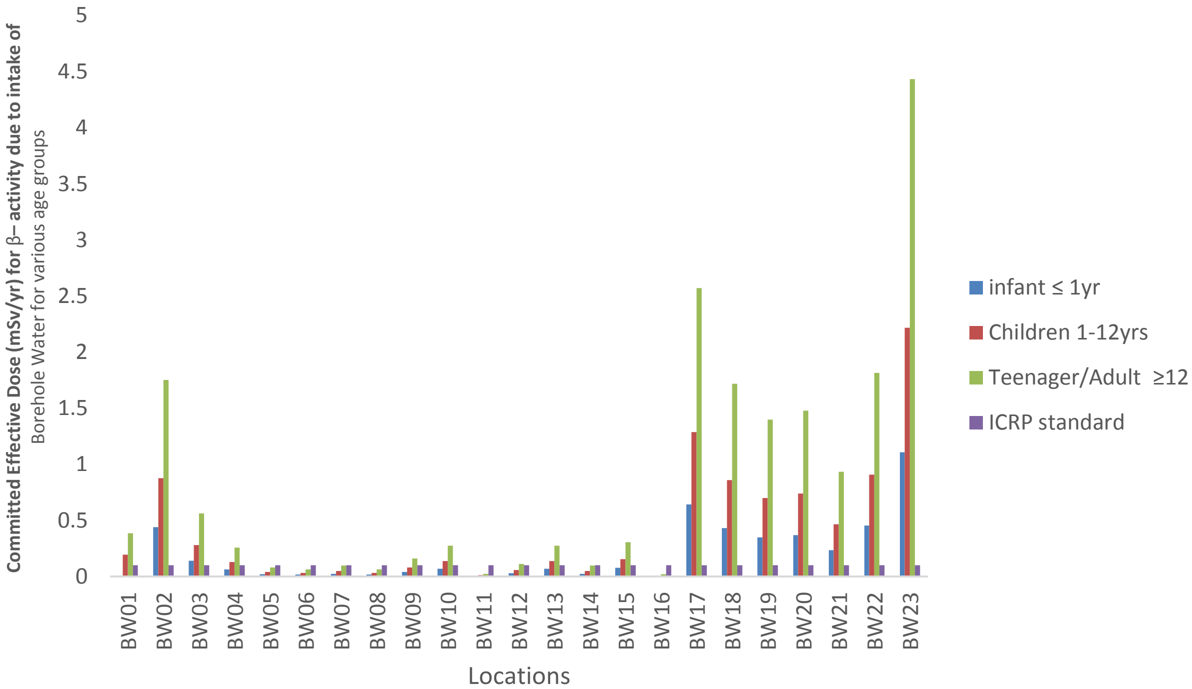

Fig 3: Comparison of Committed Effective Dose for Different Age Groups Due to Beta Radioactivity in Borehole Water with ICRP Standard.

Table 2: Gross Alpha and Beta Radioactivity concentration (Bq/L) of Well Water Samples Collected in Mining Areas in Plateau State.

				α - Annual Committed Equivalent Dose (mSv yr-1)			β - Annual Committed Equivalent Dose (mSvyr-1)		
Sample ID	**Sample Location**	**Alpha(α) Activity (Bq/L)**	**Beta(β) Activity (Bq/L)**	**infant ≤ 1yr**	**Children 1-12yrs**	**Teenager/ Adult ≥12**	**infant ≤ 1yr**	**Children 1-12yrs**	**Teenager/ Adult ≥12**
WW01	Ratatis (Dorowa)	1.840±0.020	1.540±0.023	0.739	1.478	2.955	0.618	1.237	2.473
WW02	Nafan Dredge	0.410±0.011	0.180±0.011	0.165	0.329	0.659	0.072	0.145	0.289
WW03	B/Ladi(Katako)	0.440±0.010	0.020±0.007	0.177	0.353	0.707	0.008	0.016	0.032
WW04	Sho	0.220±0.013	0.110±0.013	0.088	0.177	0.353	0.044	0.088	0.177
WW05	Rahwol Gassa	0.500±0.011	0.030±0.010	0.201	0.402	0.803	0.012	0.024	0.048
WW06	Nding	0.670±0.014	0.100±0.003	0.269	0.538	1.076	0.04	0.08	0.161
WW07	Heipang	0.870±0.014	0.280±0.012	0.349	0.699	1.397	0.112	0.225	0.45
WW08	Foron Zabot	12.590±0.025	14.640±0.033	5.055	10.11	20.22	5.878	11.756	23.512
WW09	Bisichi	0.370±0.012	0.090±0.003	0.149	0.297	0.594	0.036	0.072	0.145
WW10	Jantar Kuru	0.440±0.160	0.160±0.012	0.178	0.353	0.707	0.064	0.128	0.257
WW11	Science School Kuru	0.810±0.015	0.170±0.011	0.325	0.65	1.301	0.068	0.137	0.273
WW12	Maraba Jama'a	0.130±0.010	0.04±0.001	0.052	0.104	0.209	0.016	0.032	0.064
WW013	Ganawuri	0.010±0.008	0.070±0.003	0.004	0.008	0.016	0.028	0.056	0.112
WW014	Bum	0.021±0.004	0.270±0.003	0.008	0.017	0.034	0.108	0.217	0.434
WW015	Rim	0.150±0.011	0.040±0.001	0.06	0.12	0.241	0.016	0.032	0.064
WW16	Vom	0.260±0.014	0.130±0.010	0.104	0.209	0.418	0.052	0.104	0.209
WW17	Angul Dee	0.160±0.11	0.040±0.001	0.064	0.128	0.257	0.016	0.032	0.064
WW18	Angul Dee II	7.710±0.016	7.220±0.019	3.096	6.191	12.382	2.899	5.798	11.595
WW19	Zawan	0.570±0.016	0.440±0.018	0.229	0.458	0.915	0.177	0.353	0.707
WW20	DU	1.450±0.015	0.040±0.001	0.582	1.164	2.329	0.016	0.032	0.064
WW 21	Mai-idon-Taro	0.280±0.014	0.110±0.013	0.112	0.023	0.45	0.044	0.088	0.177
WW 22	Sot-Gyel	0.860±0.017	0.600±0.018	0.345	0.691	1.381	0.241	0.482	0.964
WW23	Sabon-Gidan Kanar	0.190±0.012	0.040±0.001	0.076	0.153	0.305	0.016	0.032	0.064
WW24	Federal Secretariat	0.270±0.040	0.760±0.060	0.108	0.217	0.434	0.305	0.61	1.221
WW25	Tudun Wada	0.580±0.080	1.540±0.120	0.233	0.466	0.932	0.618	1.237	2.473
WW26	Jenta	1.810±0.038	5.40±0.120	0.727	1.435	2.907	2.168	4.336	8.672
WW27	St. Murumba College	0.580±0.010	1.220±0.014	0.233	0.466	0.932	0.49	0.98	1.959
WW28	Students Village	1.410±0.032	2.470±0.044	0.566	1.132	2.265	0.992	1.983	3.967
WW29	Bauchi Junction	0.460±0.060	1.070±0.010	0.185	0.369	0.739	0.43	0.859	1.718
WW30	Old Police Barrack	1.420±0.014	3.000±0.020	0.57	1.14	2.281	1.205	2.409	4.818
WW31	Nasarawa Gwong	0.450±0.060	1.320±0.010	0.181	0.361	0.723	0.53	1.06	2.12
WW32	Fudawa	2.820±0.034	5.200±0.042	1.132	2.264	4.529	2.088	4.176	8.351
WW33	Furaka	0.320±0.060	0.980±0.010	0.128	0.257	0.514	0.393	0.787	1.574
WW34	Dogon karfe	0.260±0.040	0.740±0.080	0.104	0.209	0.418	0.297	0.594	1.188
WW35	Abattoir	0.910±0.012	1.700±0.014	0.365	0.731	1.462	0.683	1.365	2.73

WW: Well Water

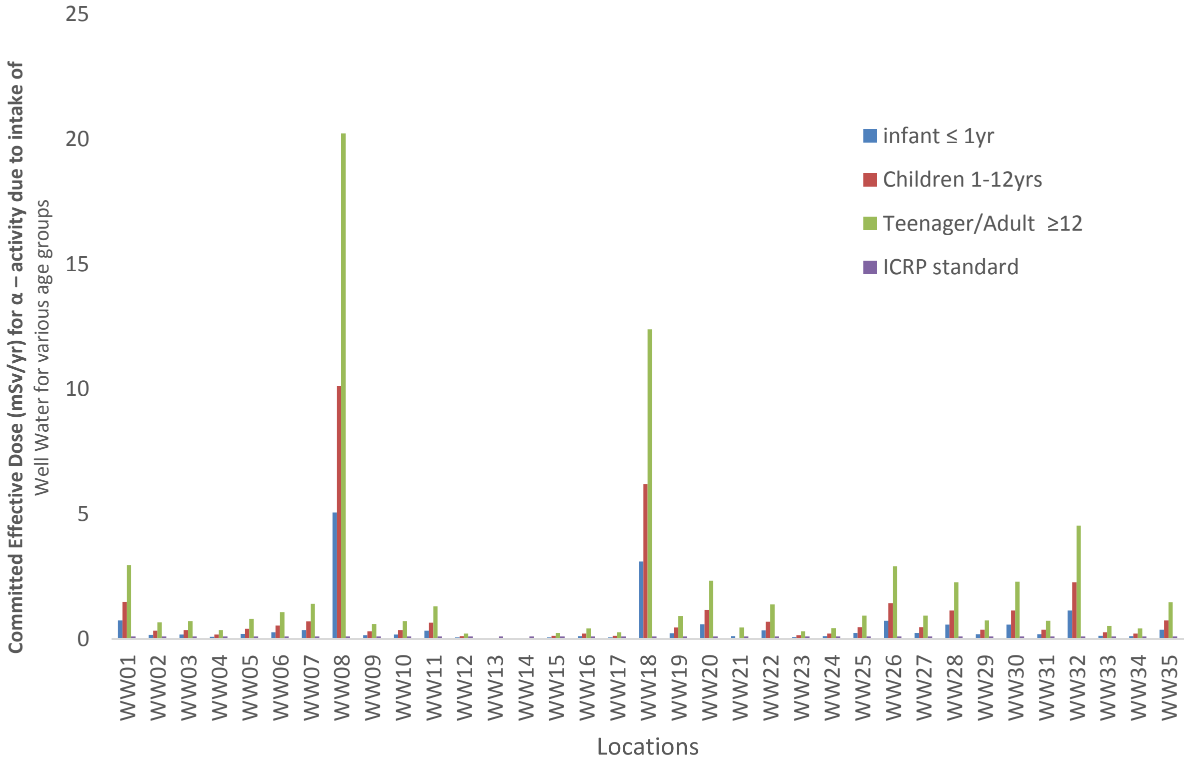

Fig 4: Comparison of Committed Effective Dose for Different Age Groups Due to Alpha Radioactivity in Well Water ICRP Standard.

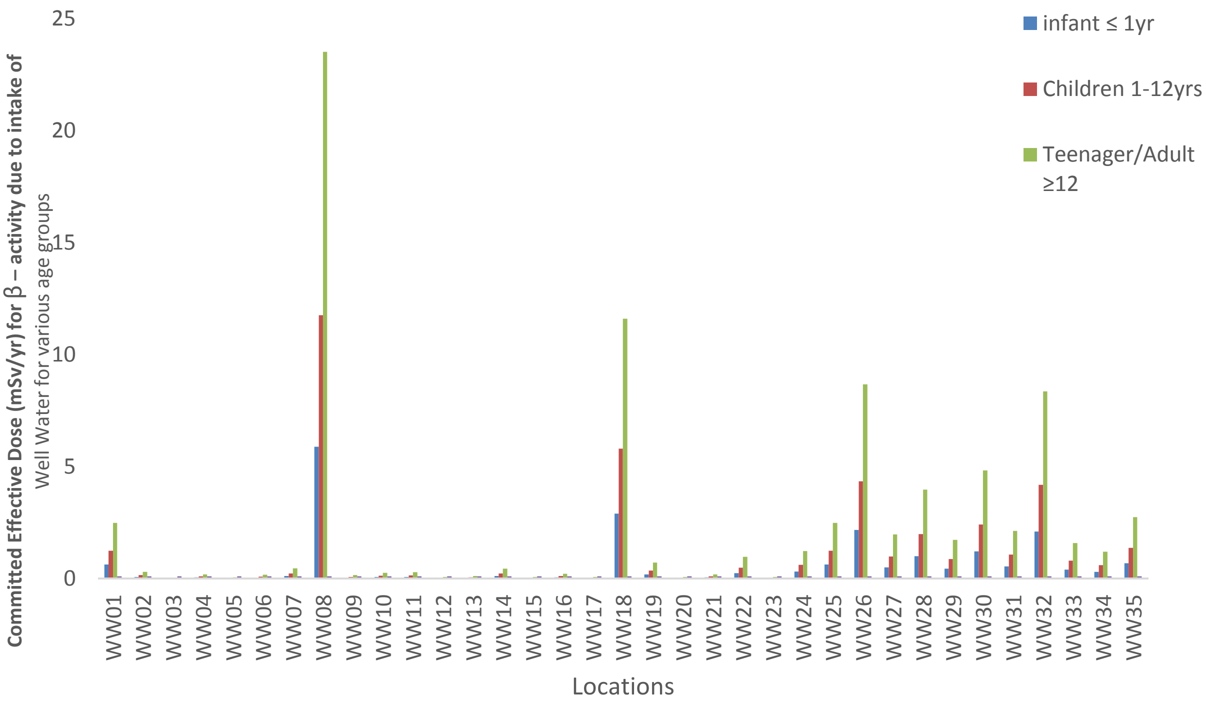

Fig 5: Comparison of Committed Effective Dose for Different Age Groups Due to Ingestion of Beta Emitting Radionuclide in Well Water with ICRP Standard.

4.1. Discussion

Tables 1 and 2 present the summary of the results of the gross alpha and beta activity concentrations in borehole and well water supplies tables also show the estimated. The results show relatively high activity concentrations in almost all the locations in the ground water supplies. These suggest that the ground water supplies from the mining areas have contaminated radiologically. Annual committed effective dose to the infants (<_) who take an average of 182.5 litres of water per year, children (1-12yrs) who take an average of 365 litres per year and teenagers/adult (> 12yrs) with water intake of 730 litres per year (ICRP, 1997) from the tables the mean values of the committed effective dose to the different age groups are 0.240msv/yr, 0.481msv/yr and 0.885msv/yr for infants, children and teenagers/adults respectively for alpha emitting radionucles in the same source are 0.20msv/yr, 0.410msv/yr and 0.820msv/yr for infants, children and adults respectively. For well water samples, the mean values of the CED for alpha activity are 0.485msv/yr, 0.963msv/yr and 1.938msv/yr for the various age groups as earlier stated. The mean CED value for beta emitting radionuclides is 0.594msv/yr, 1.187msv/yr and 2.375msv/yr for the age groups respectively.

Figures 2-5 show the comparison of committed effective dose for different age due to alpha and beta emitting radionuclide in borehole and well water samples with the ICRP standard of 0.1msv/yr (ICRP, 1997; Agbalagb). The figures reveal that all the CED values for the age groups are higher than the allowed dose contribution from water. The results show that infants, children and teenagers are mostly affected as they are more susceptible to high dose related disease through intake of water from these sources (Ononugbes et, al)

5. Conclusion

The levels of gross alpha and beta activity concentrations in groundwater supply in mining areas of plateau state have been surveyed. The experiments results obtained show that gross alpha and beta activity concentrations in most location from borehole and well water supplies are above the World Health Organization recommended guideline value of 0.5Bq/d for alpha activity and 1.0Bq/d for alpha activity and 1.0Bq/d for beat activity (WHO, 2008).

The estimated committed effective dose to the different age groups in the study area is above the ICRP guideline value. Although immediate health implication for the present level, long term accumulated health side-effects are highly probable in the affected communities. Thus, long term accumulated effects should be guided especially in the locations where elevated activity values are observed.

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