Data Article

GROSS ALPHA AND BETA ACTIVITY CONCENTRATIONS IN SURFACE WATER SUPPLIES FROM MINING AREAS OF PLATEAU STATE, NIGERIA AND ESTIMATION OF INFANTS AND ADULTS ANNUAL COMMITTED EFFECTIVE DOSE

ABSTRACT

A radiological characteristics of surface waters of the mining areas of Plateau State, Nigeria covered by the Naraguta Topographical sheet 168 was carried out in the month of March 2012. For this purpose forty – eight (48) surface water samples were collected from 25 mine ponds and 23 streams. Analysis included gross alpha and gross beta activities using MPC – 2000 – DP and estimation of committed effective Dose to the different age groups of the general public. The results obtained showed that the gross alpha activities ranged from (0.047 ± 0.010 – 6.640±0.032)Bq/l with a geometric mean of 0.410Bq/l for mine ponds samples while the gross beta activities for mine ponds ranged from (0.001±0.009-6.680±0.039)Bq/l with a geometric mean of 0.125Bq/l. Also the gross alpha activities for stream water samples ranged from (0.140±0.011 – 4.310±0.013)Bq/l with a geometric mean of 0.642 Bq/l and the gross beta activities for stream samples ranged from (0.040±0.001 – 1.170±0.018)Bq/l with a geometric mean of 0.250Bq/l. The annual committed effective dose for all age groups was calculated and they showed elevated values above the ICRP acceptable standard of 0.1mSv/yr. This implies that infants and children who are more susceptible to radiation dose through water ingestion may be exposed to high radiation health risk.

Keywords: Gross alpha, gross beta, mining areas, committed effective dose, mine ponds, streams.

INTRODUCTION

Natural occurring radioactive materials (NORM) are frequently found in surface water supplies in Plateau state as a result of the natural geology and the mechanized tin mining activities that had taken place in the area. Tin mining has a very long history in the Jos Plateau. It started in 1904 and by the mid-1920s more cassiterites(tin ores) discoveries had been made which resulted in more mechanized extraction techniques to meet the high demands in tin by 1960s – 1970s. This in turn results in high generation of radioactive wastes (tailings) (James and Edefatano, 2010). When the demand in tin gradually declined in the late 1980s, it led to abandonment of various tin mining projects without proper disposal of the huge generated wastes and mine ponds scattered all over the area. These wastes have been washed by rain water into the stream water supplies thereby causing radiological pollution. The open cast mining method was generally used in predominantly flat plains of the Plateau as tin and columbite were concentrated in old stream beds (alluvial) having been washed down from the younger granite out cropping units (James and Edefatano, 2010).

Geology of the Study Area

A major part of the Jos Plateau is underlain by non-orogenic granites of the Mesozioc Era (Macleod and Turner, 1971) generally known as the younger granites. They form a distinct metallogenic province consisting essentially of biotite granite, riebeckite biotite granite, hornblende fayalite granite, hornblende biotite granite, rhyolite, syentite, gabbro, dolerites and basalts with significant but varying amount of natural concentration of thorium, uranium and potassium which are radioactive.

Some of the rocks found here are also associated with alluvial deposits of cassiterite (tin oxide, $Sn0_2$) and columbite -oxide of tantalum – niobium, iron and manganese (Fe, Mn)(Ta, Nb)$_2$ O$_6$), as well as radioactive mineral residues such as thorite ($ThSiO_4$) ziron ($ZiSiO_4$) and monazite (Ce, La, Yt)PO_4).

The rocks in this area therefore constitute a major source of radioactivity in surface water and a major radiation exposure to the inhabitants of the area through the water they consume. The objective of this study is to measure the level of natural radioactivity in surface water within the Naraguta sheet 168 (fig 1) because of the implications of radiation on human health.

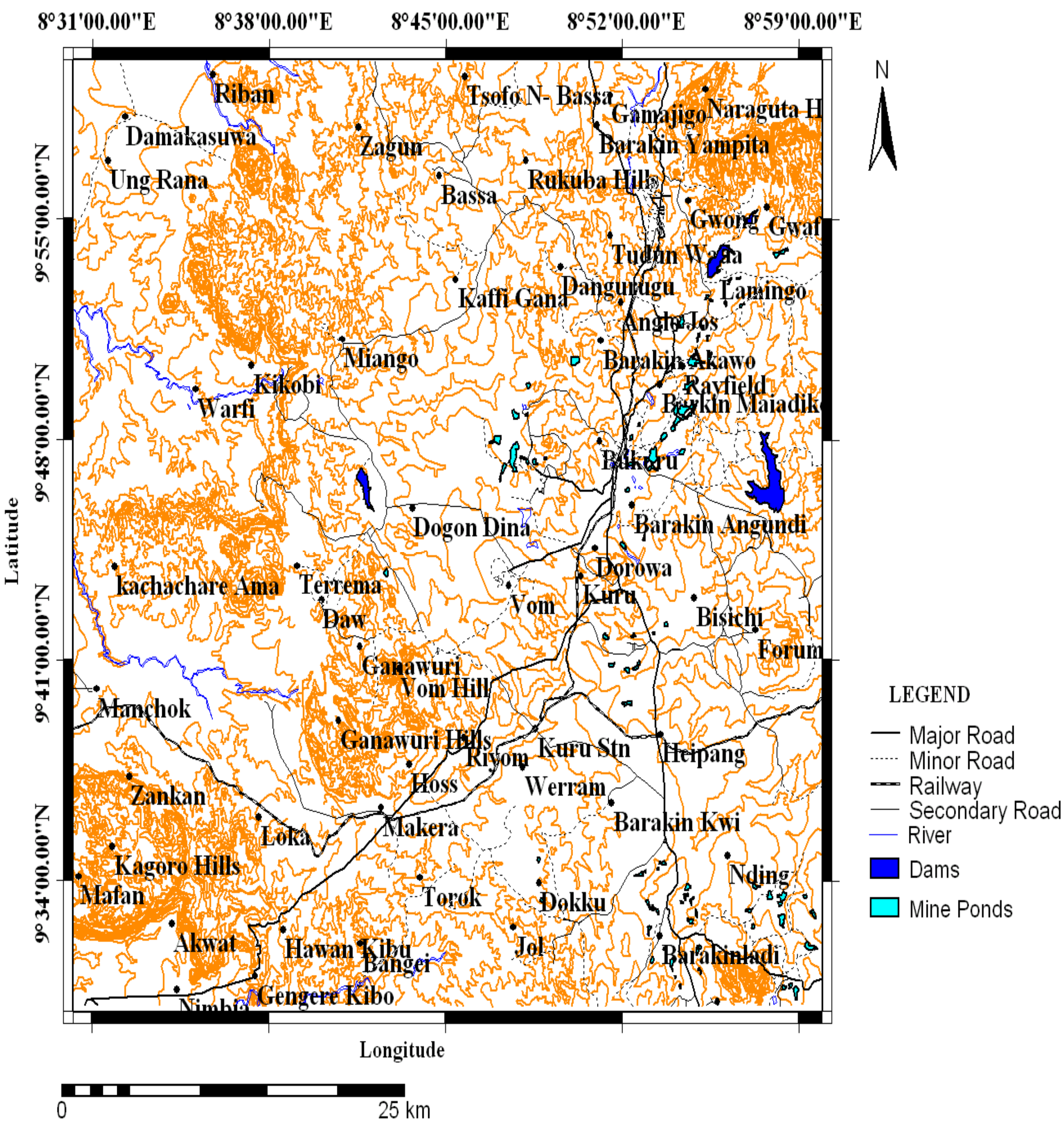

Fig 1: Naraguta Topographical sheet 168 (9°30' N to 10°00' N and8°30' E to 9°00' E)

MATERIALS AND METHODS

The field data collection was carried out in the month of March, 2012. This period was chosen because it represents the peak of the dry season when water quantity determination into another and good accessibility is enhanced. Mine ponds and streams water samples were collected in 2 litres plastic and analysed with a proportional counter – MPC – 2000 – DP. The area of sample collection is bounded between longitude $8^{0}31^{'}$E to $8^{0}59^{'}$E and latitude $9^{0}34^{'}$N to $9^{0}55^{'}$N as shown in fig 1.

At every location, the surface radiation dose was measured at the surface and 1 meter above the surface using a Gamma Scout (Water version) radiation meter. The water quality parameters (conductivity temperature, PH and Total Dissolved solids) were measured using DIST conductivity/TDS meters with automatic temperature compensation. An Etrex Garmin Global position system (GPS meter) was used to obtain coordinates and locations of the sampling points.

Sample collection and preparation

The procedure used for this work was stratified random and grid sampling of mine ponds water and streams water in the study area. Forty-eight (48) water samples consisting of twenty-five (25) mine ponds samples and twenty – three (23) streams water samples were collected from the mining areas covered by the Naraguta Topographical sheet 168. From each sampling point two litres of the water samples were drawn from each mine pond and stream source in a two litre plastic container. The amount of water collected was such that an air space of about 1% of the container capacity was left for thermal expansion. Samples were immediately acidified with nitric acid solution to reduce the pH, minimize precipitation and prevent the growth of micro-organisms. Immediately before sample collection, plastic bottles were rinsed again several times with water to be sampled. The samples were air tight and taken to the laboratory and held for atleast 24 hours before analysis.

Evaporation of samples was done using hot plates without stirring and at moderate heat in an open 600ml beaker. In the process of evaporation, when the level of the sample in the beaker was about 50ml, it was then transferred into a petri-dish and placed under infra-red light to completely dry the residue was obtained by subtracting the weight of the petri-dish from the weight of the petri-dish plus sample residue. An empty planchet was weighted 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 added on the samples to make then stick to the plancet to prevent scattering of the residue during counting.

Counting and Analyzes

The counting equipment is automated. The protocol involves entering present time, counting voltage and number of counting per cycles. Also to be entered are the counter characteristics (efficiency and background) volume of sample used and sample prepared efficiency. Results are displayed as raw count (count per minute), count rate activity and standard deviation. Acquisition was made in α – only mode and β- only mode.

The calculation formula for counter rate activity and parameters for a given sample given as (Nuhu et al, 2009).

Counter Rate (α, β) = Raw (α, β) count/count time in all modes

$$\text{Activity } (\alpha, \beta) = \frac{rate\ (\alpha,\beta) - Bqd(\alpha,B)}{sample\ efficency \times channel\ efficency}$$

Estimation of Annual Committed Effective Dose

The annual committed effective dose to an individual due to ingestion of natural radioactive material from all the water samples is estimated using the following equation (Onoja, 2011).

$$CED = A \text{ x } IW \text{ x } DCF \quad (3)$$

Where

A = Sample activity concentration (Bq/l)

IW = Water intake. The quantity of water taken by each age group in a year are (ICRP, 1997).

IW for teenage/adults (>12,yrs) is 730litres per year

IW for children (1 – 12yrs) is 365 per year

IW for infants ($\leq 1\ yr$) is 182.5 litres per year

DCF = Dose conversion factor (mSv/Bq)

Dose conversion factor used to calculate the internal radiation exposure by ingestion of radionulcides of radiological significance in drinking water for members of the public is 2.2×10^{-3} mSv/Bq (DMP, 2010).

RESULTS AND DISCUSSION

Table 1: Committed Effective Dose (mSv/yr) for α – and β – activity due to intake of Mine Pond Water for various age groups

		α - Annual Committed Equivalent Dose (mSv yr^{-1})			β - Annual Committed Equivalent Dose (mSvyr^{-1})		
S/N	**Location**	**infant ≤ 1yr**	**Children 1-12yrs**	**Teenager/Adult ≥12**	**infant ≤ 1yr**	**Children 1-12yrs**	**Teenager/Adult ≥12**
1	Ratatis(Dorowa)	0.197	0.393	0.787	0.036	0.072	0.145
2	Kari	0.289	0.578	1.156	0.249	0.498	0.996
3	Sabon Layi (B/Ladi)	0.056	0.112	0.225	0.008	0.016	0.032
4	Police Barrack (B/Ladi)	0.072	0.145	0.289	0.273	0.546	1.092
5	Workshop (B/Ladi)	0.019	0.038	0.076	0.039	0.078	0.156
6	Sho Road	0.225	0.450	0.899	0.004	0.008	0.016
7	Rim	0.145	0.289	0.578	0.056	0.112	0.225
8	Rahwol Gassa	0.084	0.169	0.337	0.028	0.056	0.112
9	Heipang	0.177	0.353	0.707	0.116	0.233	0.466
10	Foron Zabot	0.080	0.161	0.321	0.001	0.001	0.002
11	Jantar Kuru	0.169	0.337	0.675	0.096	0.193	0.385
12	Bisichi	2.666	5.332	10.664	2.682	5.364	10.728
13	Angul Dee	0.201	0.402	0.803	0.004	0.008	0.016
14	Zawan	0.060	0.120	0.241	0.028	0.056	0.112

15	Mai Idon Taro	0.137	0.273	0.546	0.044	0.088	0.177
16	Mai Idon Taro B	0.494	0.988	1.975	0.454	0.907	1.815
17	Sot-Gyel	1.068	2.136	4.272	0.100	0.201	0.402
18	Sabon Gidan Kanar	0.249	0.498	0.996	0.024	0.048	0.096
19	Vom	0.092	0.185	0.369	0.004	0.008	0.016
20	Kwan	0.096	0.193	0.385	0.153	0.305	0.610
21	Doi-Du I	0.246	0.491	0.983	0.165	0.331	0.662
22	Doi-Du II	0.213	0.426	0.851	0.137	0.273	0.546
23	Gura-Topp	0.193	0.385	0.771	0.116	0.233	0.466
24	TCNN	0.145	0.290	0.560	0.209	0.418	0.835
25	Rayfield Resort	0.117	0.234	0.467	0.028	0.056	0.112
	Standard ICRP 1997	0.100	0.100	0.100	0.100	0.100	0.100

Table 2: Committed Effective Dose (mSv/yr) for α – and β – activity due to intake of Stream Water for various age groups

		α - Annual Committed Equivalent Dose (mSv yr^{-1})			**β - Annual Committed Equivalent Dose (mSvyr^{-1})**		
S/N	**Location**	**infant ≤ 1yr**	**Children 1-12yrs**	**Teenager/ Adult ≥12**	**infant ≤ 1yr**	**Children 1-12yrs**	**Teenager/ Adult ≥12**
1	Ratatis(Dorowa)	0.317	0.634	1.269	0.132	0.265	0.530
2	Nafan Dredge	0.618	1.237	2.473	0.470	0.940	0.272
3	Ropp	0.418	0.835	1.670	0.241	0.482	0.964
4	Barkin ladi	0.173	0.345	0.691	0.100	0.201	0.402
5	Sho	0.221	0.442	0.883	0.040	0.080	0.161
6	Rahwol Gassa	0.506	1.012	2.024	0.333	0.667	1.333
7	Heipang	0.072	0.145	0.289	0.016	0.032	0.064

8	Foron Zabot	0.249	0.498	0.996	0.470	0.940	1.879
9	Bisichi	1.730	3.461	6.922	0.201	0.402	0.803
10	Jantar Kuru	0.249	0.498	0.996	0.092	0.185	0.369
11	Maraba Jama’a	0.454	0.907	1.815	0.157	0.313	0.626
12	Rim	0.197	0.393	0.787	0.036	0.072	0.145
13	Hoss	0.108	0.217	0.434	0.016	0.032	0.064
14	River Kaduna	0.410	0.819	1.638	0.225	0.450	0.899
15	Vom	0.056	0.112	0.225	0.016	0.032	0.064
16	Angul Dee	0.233	0.466	0.932	0.072	0.145	0.289
17	Du	0.149	0.297	0.594	0.108	0.217	0.434
18	Gyel	0.265	0.530	1.060	0.161	0.321	0.642
19	Sot-Gyel	0.349	0.699	1.397	0.153	0.305	0.610
20	Rayfield	0.132	0.265	0.530	0.088	0.177	0.353
21	Gura-Zot	0.108	0.217	0.434	0.017	0.033	0.066
22	British American Junction	0.855	1.710	3.421	0.450	0.899	1.799
23	Tina Junction	0.265	0.530	1.060	0.100	0.201	0.402
	Standard ICRP 1997	0.100	0.100	0.100	0.100	0.100	0.100

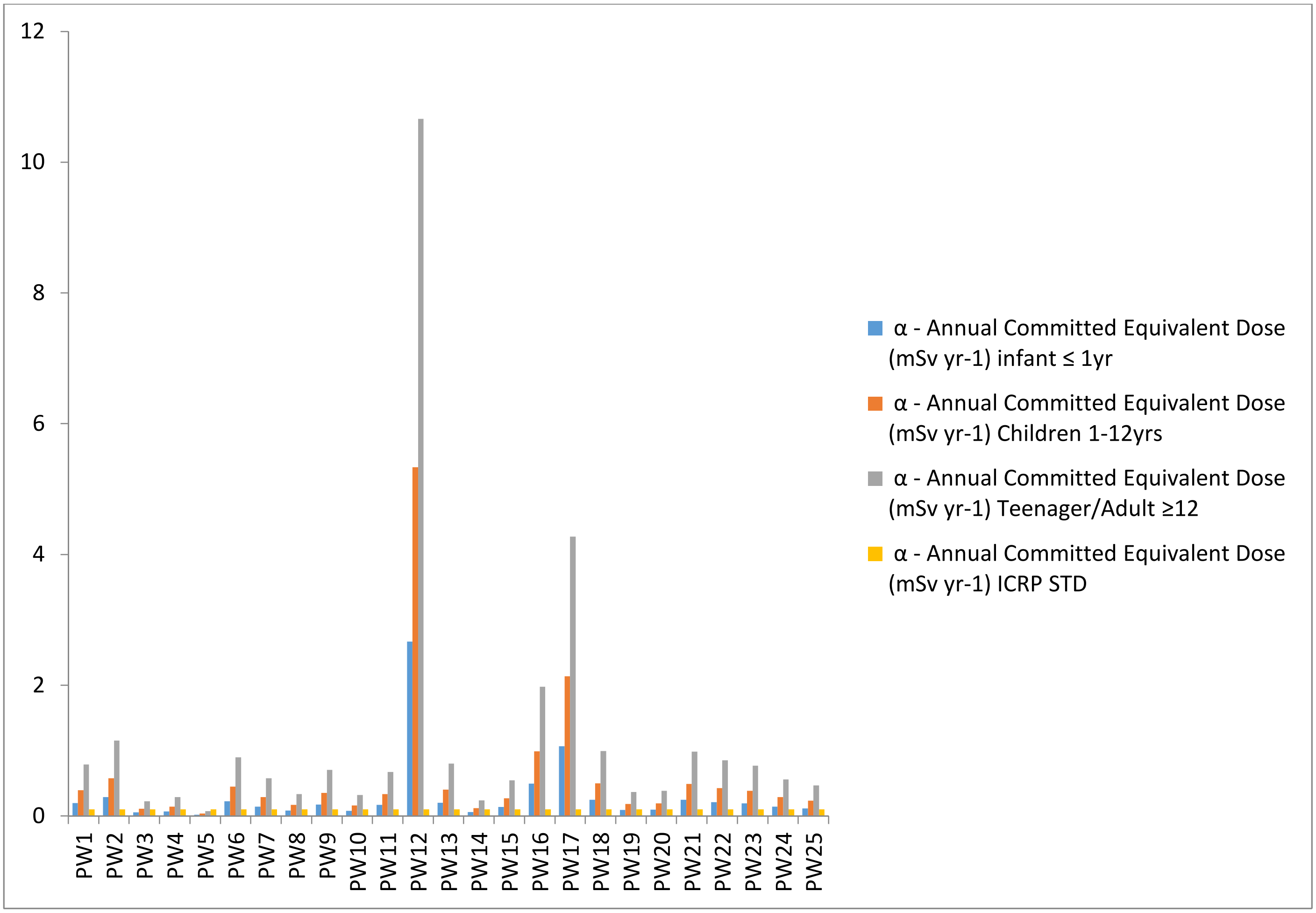

Fig.2: Comparison of committed effective dose for different age group due to alpha activity in mine ponds.

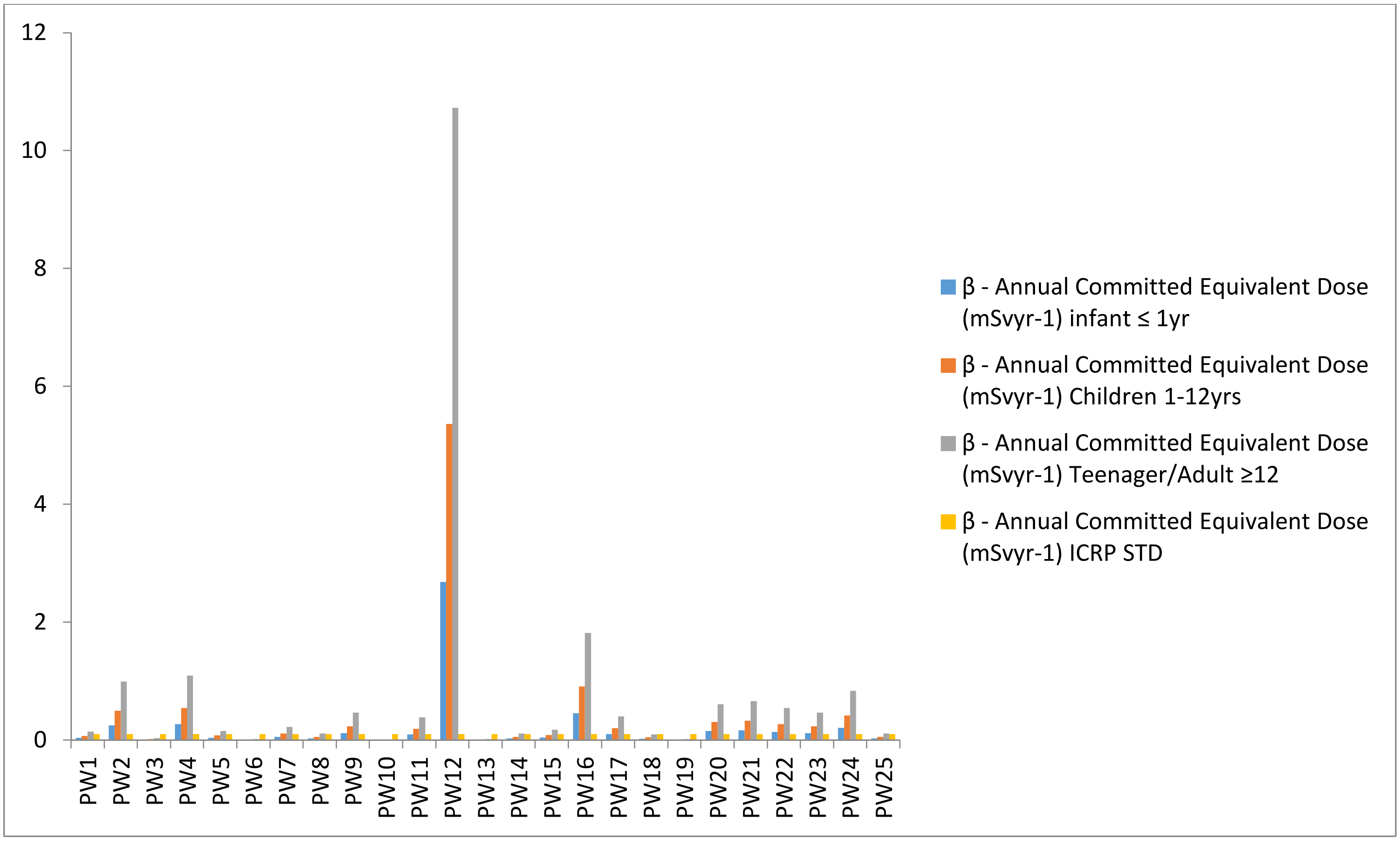

Fig.3: Comparison of committed effective dose for different age group due to beta activity in mine ponds.

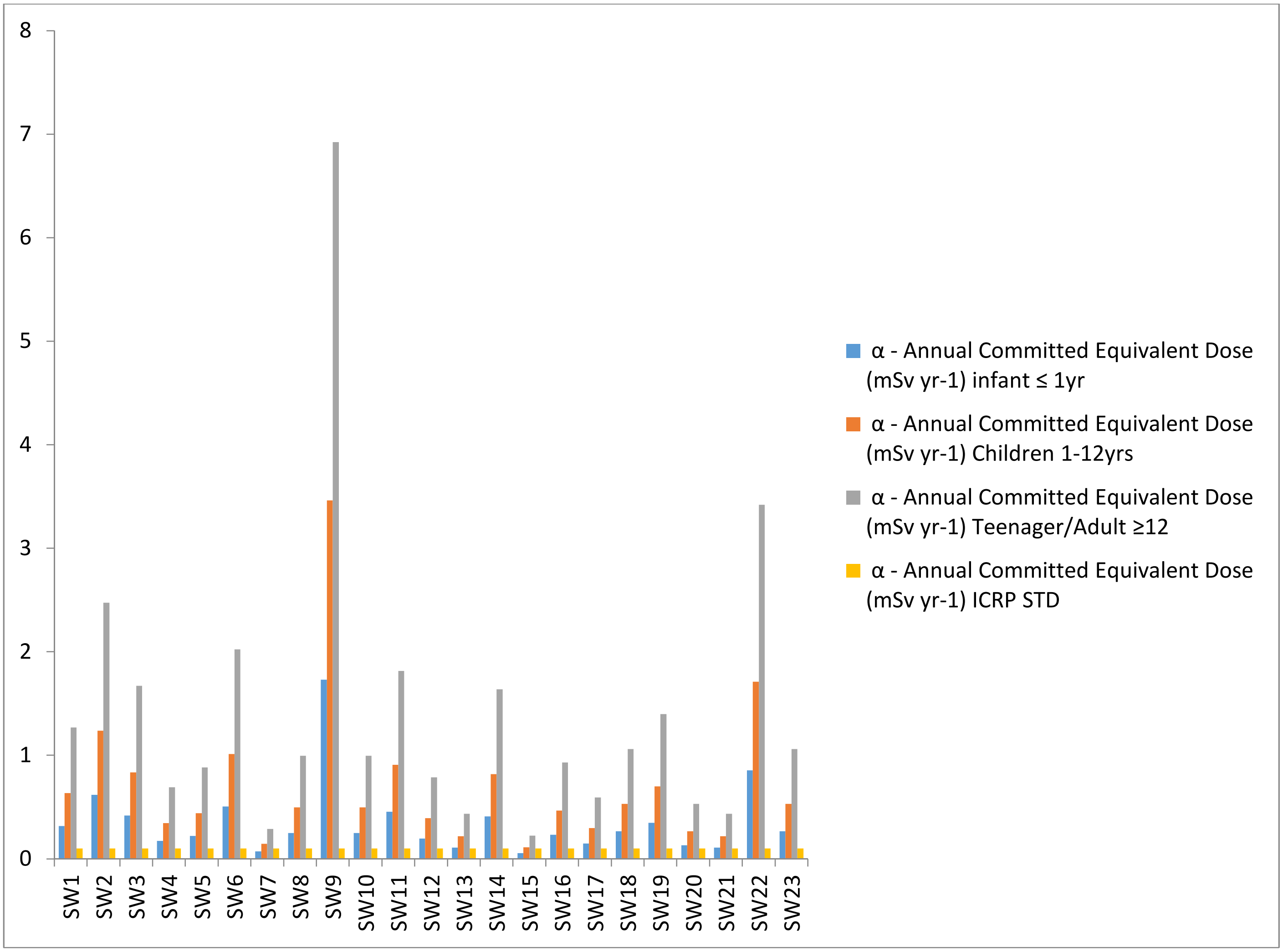

Fig.4: Comparison of committed effective dose for different age group due to alpha activity in streams.

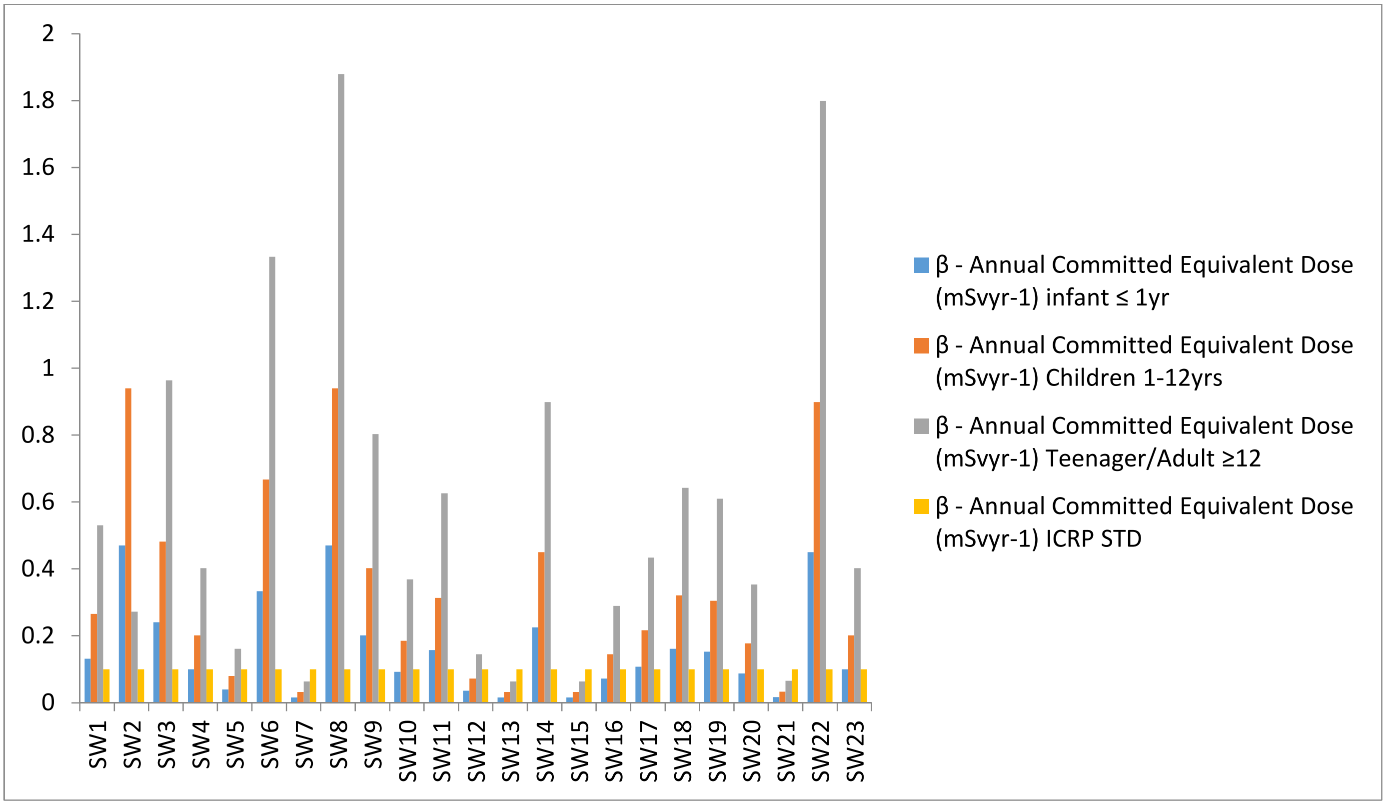

Fig.5: Comparison of committed effective dose for different age group due to beta activity in streams.

Tables 1 and 2 present the gross alpha and gross beta activities in mine ponds and streams water samples in the mining areas of Plateau State and the estimated Annual Committed Effective Dose. The alpha activities ranged from (0.047±0.010-6.640±0.032) Bq/land beta activities ranged from (0.001±0.009-6.680±0.039)Bq/l for mine ponds .For stream water samples,the gross alpha activities ranged from (0.140±0.011-4.310±0.013) Bq/l and the gross beta activities ranged from (0.040±0.001-1.170±0.018) Bq/l.

From table 1, the mean values of the annual committed effective dose to the infants,children and adults for alpha activities are 0.300mSv/yr, 0.599mSv/yr and 1.197mSv/yr for mine pond water samples while the mean values for beta emitting radionuclides are 0.202mSv/yr, 0.404mSv/yr and 0.809mSv/yr for the same sources. For stream water samples,the mean values of the CED for alpha emitting radionuclides are 0.354mSv/yr ,0.707mSv/yr and 1.415mSv/yr and the mean values of the CED for beta emitting radionuclides are 0.161mSv/yr,0.321mSv/yr and 0.573mSv/yr .It is observed that all the values are above the ICRP guideline value of 0.1mSv/yr(ICRP,1997;Agbalagba and Avwiri,2012).

Figures 2,3,4 and 5 show the comparison of committed effective dose for the different age groups due to alpha and beta emitting radionuclides in mine ponds and streams water samples with the ICRP standard of 0.1mSv/yr. The figures clearly reveal that that all the CED values for the age groups are above the allowed dose contribution from water intake. Although the CED values for teenagers and adults are higher than for infants and children due to higher quantity of water intake, the infants and children are more susceptible to high radiation dose related diseases through water ingestion due to their growing body cells. (Ononugbo, et al, 2013).

CONCLUSION

This study measured the gross alpha and gross beta radionuclides activities and also estimated the annual committed radiation dose in surface water in Tin mining environment of Plateau State. The gross alpha and beta activity concentrations in mine ponds and streams vary in quantity from one location to the other. The estimated dose intake for infants, children andteenagers/ Adults also showed variation between the sources. The enhanced radionuclides concentration levels observed in some mine ponds locations and streams can be attributed to the radionuclides exposed during mining and the radioactive tailings that are washed into same streams. We conclude that the generally high radioactivity levels observed in the study area have been influenced by mining activities and the indiscriminate disposal of mine tailings without following laid down regulations for this purpose.

We therefore recommend that areas with very high activity concentrations should not beused for drinking, agricultural and recreational activities by the host communities.

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