Journal of the Nigerian Association of Mathematical Physics
Volume 62, (October – Dec., 2021 Issue), **pp127 – 132**

ASSESSMENT OF ANNUAL EFFECTIVE DOSE ASSOCIATED WITH RADON-222, GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN GROUND WATER AROUND ZURMI GOLD MINING ENVIRONS, ZAMFARA STATE, NIGERIA

M. U. Ibrahim[1,3] N. Abdulazeez[1, 2], A. S.Gidado[1], and F. Ahmed[1,3]

[1]Department of Physics, Bayero University, Kano-Nigeria
[2]Department of Science Laboratory Tech, Federal Polytechnic Kaura Namoda, Zamfara-Nigeria
[3]Center for Renewable Energy Research, Bayero University Kano

Abstract

Radiological contamination in ground water is a serious health issue, which could be devastating and possibly cause cancer. In this work, preliminary studies on Gross Alpha/Beta radioactivity and Radon-222 concentration in ground water around Zamfara environs (Tungan shaho, Dada and Nasarawa) were analyzed. Samples of ground water were collected, from ten points, by random sampling technique. Subsequently, measurements of activities were carried out using a Non-gas proportional counter for Gross Alpha/Beta activity and liquid scintillation counter for radon-222 concentrations. Results of the analysis showed that, the Gross Alpha activity ranges from 0.33–0.55 (Bq/L) while that of Beta ranges from 0.53–0.63 (Bq/L) with arithmetic mean of 0.469 and 0.588(Bq/L) respectively. Similarly, the Radon concentration ranges from 49.45-30.42(Bq/L), with arithmetic mean of 35.51.41(Bq/L). however, only five samples out of ten has concentrations, higher than the maximum permissible limits of drinking water set at 0.5 and 11.1Bq/L respectively, as stipulated by the United States Environmental Protection Agency (USEPA) and the World Health Organization (WHO). However, the average annual effective doses due to the gross alpha/beta activity and radon-222 concentrations were 0.754, 0.224, 0.259 mSv/year for adults, 0.380, 0.153, 0388 mSv/year for children and 0.188, 0.136, 0.434 mSv/year for infants. These values are higher, except the gross beta that is within the limit of 0.1mSv/year set by WHO and EU. However, these effects could be to be mitigated as indicated by USEPA.

Keyword: Gross Alpha, Gross Beta, **^{222}**Radon, Ground water, annual effective dose,

INTRODUCTION

The general purpose of water cannot be over emphasized. It is a constituent of all living things, used in various aspects, such as power generation, agriculture, drinking and domestic activities. Therefore, quality drinking water must be certified, free from all form of contaminations. Consequently, radiological contaminations in drinking water, pose a serious health challenges, which may result to cancer or other related diseases [1]. Radon is a natural occurring radioactive element, contributing a bigger portion to water contamination. It is a colorless, odorless, tasteless noble gas family, existing as ^{222}Radon decaying with half-life of 3.824 days; ^{224}Rn and ^{219}Rn with half-lives of 55.6s and 4s respectively. These isotopes are produced by alpha decay of ^{226}Ra, ^{224}Ra and ^{223}Ra, a decay product of ^{238}U, ^{232}Th and ^{235}U respectively. Among others, ^{222}Rn is seen as the most concern, as others have short half-lives, which could not be measured [2]. Alpha emitters occur in ground water, naturally or man-made as radioactive contaminants. Beta and photon emitters are primarily man made contaminants associated with operating nuclear power plant, facilities that use radioactive material for research or manufacturing. However, some beta emitters occur naturally [3].

Factors, such as geological formation, geochemical properties of parent radionuclide, hydrological conditions and abundance

Corresponding Author**:** Ibraham M.U., Email: umibrahim.phy@buk.edu.ng, Tel: +2348037375353

of parent radionuclide are the possible potential parameters which could determine the concentration of gross α and β radioactivity in ground water [4]. Ground water could be contaminated with alpha emitter such as ^{238}U, ^{235}U, ^{232}Th, ^{226}Ra, ^{210}Po and beta emitters such as ^{40}K, ^{228}Ra and ^{210}Pb due to radioactivity bearing tailings [5]. Radon could decays into lungs, emitting a damaging alpha particles with its daughter ^{218}Po, which is not chemically inert is likely to stay in the lungs until it decays, emitting another damaging alpha particles down the series [6].

Quantification of radiological contamination is very vital, for the purpose of public health, it was estimated that about 50% of the total annual effective dose due to natural source emanates from radon and its progeny when inhaled or ingested [7]. Determination of radiological contamination due to radon-222, gross alpha and beta radioactivity helps to estimate the radiological consequences associated with the utilization of ground water in an area which is consider to having important factor for natural radiation exposure in the populace [8]. This kind of research has been carried out elsewhere, within and outside Nigeria, revealing a variation activity concentration, due to geological and atmospheric factors. In Zurmi environs where, this research was carried out, small scale artisanal gold mining has been so rampant for decades and so, environmental impact assessment is yet to be carried out.

Ionizing particles could be devastating, as their concentrations in drinking water must be not exceeds the contamination limits of 11.1, 0.5 and 1.0 Bq/l respectively as recommended. Screening of gross alpha and gross beta emitters in water is preliminarily first recommended [9].this work could be seen as first attempt to analyzed the level of radiological contamination due to radon-222, gross alpha and gross beta radioactivity in this areas and could also be useful to environmental impact assessment.

METHODOLOGY

Study Areas

This research area covers the communities in Zurmi gold mining environs, which are located in the northern senatorial district of Zamfara state. These communities are proximate to the mining sites; rely only on ground water, which is their source of drinking water, for the entire population of 110,173 as at the 2006 census.

Sample Collection

Random sampling technique was adopted for the sample collection to enable equal chance of selection to all the locations in accordance to the guidelines [2]. A total of twenty (20) samples, of ground water were collected into one and two liters of bottle respectively, from the studied areas. At the point of collection, the two liters of the samples were each acidified with trioxide nitrate acid for preservation and absorption of activities by the walls of the containing bottle.

Sample Preparation for Gross Alpha and Gross Beta Radioactivity measurements in Water

The samples were prepared in accordance with the standard procedures reported by [8]. Two liters of sample each in an open beaker was subjected to gradual evaporation on temperature adjustable hot plates. It takes an average of 24-hours to complete the evaporation of one liter. In the process of evaporation, when the sample in the beaker was about 30ml, it was then transferred to a Petri- dish and place under an infrared ray for complete surface drying of the residue. Subsequently, the residue was allowed to cool before weighing into planchette. The weight of the residue was determined by subtracting the weight of the empty Petri-dish from the weight of Petri-dish plus sample residue. An empty planchette was weight after which little quantities (≤ 0.077g) of the residues was transferred to the planchette. The planchette and the residue were then weighted. Subsequently, few drops of vinyl acetate were spread on the residue to make them stick to the planchette during counting. The volume v, of sample that produced the residue of 0.077g was estimated, using the equation below [10].

$$0.077g \times V_T = T_R V \quad (1)$$

where V_T = Volume of total residue; T_R = Weight of the total residue; V= Volume of 0.077g of residue

The volume of water which gave the total residue was also determined by the equation

$$V = \frac{VTR}{T} \times R_P \quad (2)$$

where, V = Volume of water; T_R = Total residue to be obtain; R_P = Residue of Plan chet

Hence, the sample preparation and sample efficiency were obtained respectively as.

$$\text{Sample Preparation Efficiency} = \frac{weight\ of\ residue}{0.077g} \times 100\% \quad (3)$$

$$\text{Sample efficiency} = \frac{\rho}{TR} \times 100\% \quad (4)$$

where; R_P = Sample of residue on Plan Chet; T_R =Total sample of residue from evaporation

Sample Preparation for Radon-222 Concentration in Water

The samples were prepared in accordance with the standard procedures reported by Biawas and Begon [3]. Ten ml of sample each were carefully added to the liquid scintillation vial, which were already containing ten ml of scintillation liquids, using a disposable syringe to minimize out-gassing the sample by aeration. The mixtures were vigorously shaken, to extract radon-

222 from water phase to the organic scintillation solution due to its solubility in organic liquids. Subsequently, the mixtures were allowed to stayed for at lest three hours, for in growth of the short-lived decay products of radon-222 and attainment of secular equilibrium. **Counting of Gross Alpha and Gross Beta Radioactivity in Water**

The dissolved solid (TDS), were counted for the Gross alpha and Gross beta activities respectively, using a non-gas proportional counter, for five cycles respectively. Prior to counting, Plateau test was run with calibration standards ;Pu-239 and Sr-90 sources respectively, with efficiencies and detection limits of 87.95% and 0.21cpm for alpha; similarly 42.06% and 0.22cpm for beta as specified, while the detector background count rates Were 0.60cpm for alpha and 0.70cpm for beta. Hence, the gross alpha and gross beta activities concentrations (Bq/L) were directly obtained from the equation [4].

$$\frac{\alpha}{\beta}\ \text{activity} = \frac{\alpha \text{ or } \beta \text{ count rate} - \text{BKG count rate}}{\beta \text{ sample eff} \times \text{sample size} \times \text{detector eff}} \times 0.016 \qquad (5)$$

Assessment of Annual Effective Dose Due to Gross Alpha/Beta activity

The annual effective dose to an individual person due to intake of gross alpha/beta emitting radionuclide from water samples was estimated using equation (8). The Dose Conversion factor exposure by ingestion of radionuclide of radiological significance in drinking water for members of the public is 2.2 x10^{-3} mSv/Bq, reported by Onoja [10]

$$D_{ef} = A\ {}^{\alpha}\!/\beta\ I\ R \qquad (6)$$

where: DCF = Dose conversion Factor (mSv/Bq); $A^{\alpha}{}_{/\beta}$ = Activity (Bq/L) , IRW = Intake of water by an adult (>12yrs) in a year = 730 Liters (2L/day); infant (≤1yr) = 182.5L/y; and a child (1-12yrs) in a year = 365L.

Counting of Radon-222 Concentrations in Water

Measurement of Samples was done at interval of sixty (60) minutes using a liquid scintillation counter. However, prior to the counting, the counter was calibrated using IAEA ^{226}Ra standard solution. After counting, the activity concentrations were evaluated by considering the sample volume, total and background count rates, decay time (time between sample collection and counting), and efficiency of detection. Hence Radon concentrations in each of the samples were determined using the equation [1].

$$\text{Rn}\left(\frac{\text{Bq}}{\text{L}}\right) = \frac{100\times(N_S - N_B)e^{\lambda t}}{60\times5\ \times0.964} \qquad (7)$$

where; R_n= ^{222}Rn concentration at the time of sample collection (Bq/L);N_S = sample total count rate (count min.$^{-1}$); N_B= Background count rate (count min^{-1}); N =Net count rate (count min.$^{-1}$) t = Elapsed time between sample collection and counting (4320min; 3days) **λ** = ^{222}Rn decay factor (1.26 x 10-4 min.$^{-1}$). Notes: 100 is a conversion factor from 10 ml to per liter; 60 is also a conversion factor from min. to seconds; 5 (500%) is number of emissions per disintegration of ^{222}Rn (3α and 2β, assuming 100% detection efficiency for each); and 0.964 is the fraction of ^{222}Rn in the cocktail contained in the vial of the mixtures.

Assessment of Annual Effective Dose Due to Radon in Drinking Water

The average annual effective dose due to ingestion of radon in ground water was estimated using equation (8) as provided by the World Health Organization (WHO) and USEPA, reported by [2].

$$C_{ing}{}^{Rn} = C_w{}^{Rn} * \text{I}_a * \text{D}_{f1} \qquad (8)$$

where; $C_w{}^{Rn}$= Radon concentration in water (Bq/L) $C_{ing}{}^{Rn}$ = annual effective dose from drinking water containing Radon (Sv/y)

Ia = Water consumption rate (L/y), according to "ICRP standard man" were these adopted, for adults and children, as; 2.0, 1.5 and 0.5 liters per day (Equivalent to 730, 547.5 and 182.5litres per year) respectively; D_{f1}= Ingestion dose conversion factor of Rn-222 (Sv/Bq), for adults, children and infants given, as 10^{-8}nSvBq^{-1}, 2×10^{-8} nSvBq^{-1} and 7×10^{-8} nSvBq^{-1} respectively.

RESULTS AND DISCUSSION

Table 1: Gross Alpha and Gross Beta Activities Results

S/N	Sample ID	Sample Location	A_α (Bq/L)	Error ±	A_β (Bq/L)	Error ±
1	ZW1	N- project	0.459	0.003	0.561	0.006
2	ZW2	N- low cost	0.444	0.003	0.533	0.007
3	ZW3	N-old station	0.436	0.004	0.623	0.008
4	ZW4	N- river side	0.332	0.003	0.589	0.007
5	ZW5	N- mosque	0.317	0.001	0.555	0.003
6	ZW6	T- solar	0.543	0.016	0.616	0.022
7	ZW7	T- mosque	0.543	0.014	0.627	0.020
8	ZW8	T- school	0.549	0.015	0.576	0.020
9	ZW9	D- mosque	0.531	0.014	0.609	0.021
10	ZW10	D- solar	0.541	0.014	0.589	0.020

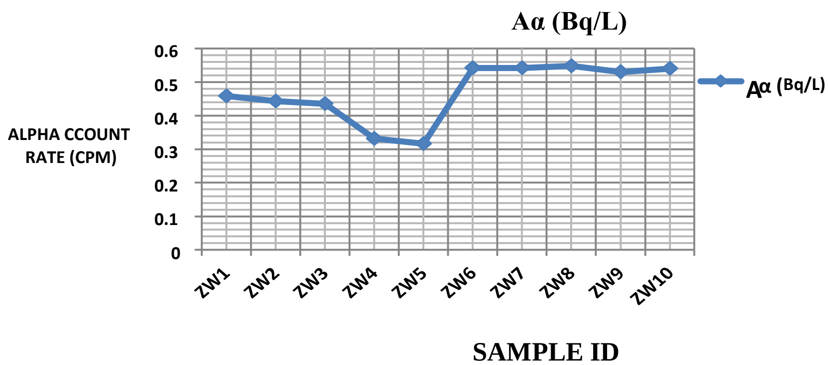

Figure 1: Gross Alpha Activity

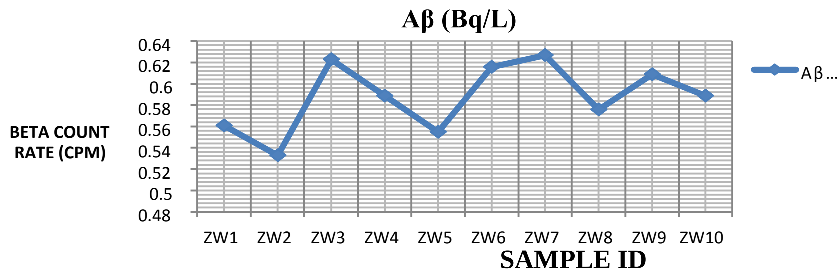

Figure 2: Gross Beta Activity

Table 2: Annual Effective Doses Due to the gross α and gross β activity

S/N	Sample ID	Sample Location	AED$_\alpha$ (mSv/year)			AED$_\beta$ (mSv/year)		
			Adult	child	Infant	Adult	child	Infant
1	ZW1	N-project	0.737	0.369	0.184	0.101	0.150	0.125
2	ZW2	N-low cost	0.713	0.357	0.178	0.156	0.128	0.114
3	ZW3	N-old station	0.700	0.350	0.175	0.100	0.106	0.150
4	ZW4	N-river side	0.533	0.267	0.133	0.146	0.173	0.136
5	ZW5	N-mosque	0.509	0.255	0.127	0.191	0.146	0.123
6	ZW6	T-solar	0.872	0.436	0.218	0.189	0.195	0.147
7	ZW7	T-mosque	0.872	0.436	0.218	1.007	0.103	0.152
8	ZW8	T-school	0.882	0.441	0.220	0.125	0.163	0.131
9	ZW9	D-mosque	0.853	0.426	0.213	0.178	0.189	0.145
10	ZW10	D-solar	0.867	0.434	0.217	0.146	0.173	0.136

Gross Alpha/Beta activity concentration and the resulting effective doses

In this work, table 1 show the preliminary test results of gross alpha and gross beta activities concentration (Bq/L), ranging from 0.317 - 0.549 Bq/l, for alpha particle and 0.533 - 0.627 Bq/l for beta particles with arithmetic mean of 0.470 Bq/l and 0.588 Bq/l respectively. However, the Samples collected from Tungan Shaho and Dada has the highest gross alpha activities above the permissible limit of 0.5 and 1.0 Bq/L for the quality drinking water set by USEPA. This may also suggest a high concentration of radon in these areas. Entirely, the gross beta activities indicated a wide spread safety level. However, these results were compared with literature values in table

5. Similarly, annual effective doses due to ingestion of gross alpha and gross beta were; 0.750, 0.224 mSv/year for adults; 0.380, 0.153 mSv/year for children and 0.188, 0.136 mSv/year for infants, respectively. These values, indicates that only the children and infants has radiological contamination due beta that is within the safety limits 0.1µSv/year, as recommended by world health organization (WHO) and European Union (EU).

Table 3: Radon -222 Specific concentration (Initial Results)

S/N	Sample ID	Sample Location	Latitude (°)	Longitude (°)	Rn-222 Activity (Bq/L)
1	ZW1	N- Project	12.62	6.65	36.51
2	ZW2	N- River Side	12.67	7.12	30.42
3	ZW3	N- Old Station	12.95	6.54	34.79
4	ZW4	N- Low Cost	13.39	6.46	30.81
5	ZW5	N- Mosque	12.54	6.74	33.97
6	ZW6	T- Solar	12.81	6.95	39.18
7	ZW7	T- School	12.78	6.77	49.45
8	ZW8	T- Mosque	12.94	6.55	33.59
9	ZW9	D- Mosque	12.79	7.00	33.96
10	ZW10	D- Solar	12.91	6.97	32.39

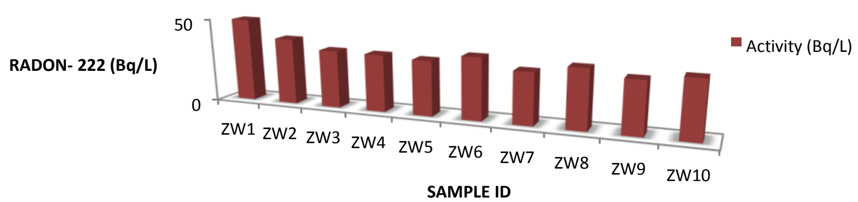

Figure 3: Initial Radon-222 Activities

Table 4: Annual Effective Doses Due to Rn-222, at initial concentrations

S/N	Sample ID	Sample Location	AED (Ing(A)	year) Ing(C)	Ing(I)
1	ZW1	N-project	361	541	632
2	ZW2	N-low cost	286	429	501
3	ZW3	N-old station	248	372	434
4	ZW4	N-river side	245	368	429
5	ZW5	N-mosque	236	355	414
6	ZW6	T-solar	267	400	466
7	ZW7	T-mosque	222	333	389
8	ZW8	T-school	254	381	444
9	ZW9	D-mosque	225	337	394
10	ZW10	D-solar	248	372	434

Radon-222 Activity Concentration and Its Annual Effective Doses

The Radon concentration (Bq/l) determined, in this work were presented in table 3, showing that, the highest activity of 49.45 (Bq/l) was recorded from sample one (Tungan Shaho) and the lowest activity of 30.42 (Bq/l) recorded from sample seven (River Side), with arithmetic mean of 35.51.98 (Bq/l), tripling the maximum permissible level of 11.1 and 10 Bq/L set by United States Environmental Protection Agency (USEPA) and World Health Organization (WHO) respectively. This result suggested that, radon concentrations in all the samples were very high and needs to be mitigated. Similarly, the annual effective doses for the ingestion of the radon-222 concentrations were 0.260, 0.388, and 0.450mSv/year for adults, children and infants respectively. However, these values indicated that, the entire the samples have radiological contamination that is above the safety limit (0.1mSv/year), as recommended by WHO and EU.

Tab 5: comparison of gross alpha and beta concentration with literature values

S/N	Region/country	A_α(Bq/L)	A_β(Bq/L)	References
1	Zurmi - Nigeria	0.317-0.549	0.533-0.627	This work
2	Shanono-Bagwai, Nigeria	0.024 - 0.066	0.007- 1.326	[02]
3	Bangladesh	(0.45-1.36) x10^{-3}	(76.0-9.80) x10^{-3}	[3]
4	Kaduna south	0.02-0.08	0.01-3.0	[15]
5	Aliero, Nigeria	0.006 - 0.079	0.804 - 4.230	[06]

Table 6: comparison of radon concentration with literature values

S/N	Water type	Radon activity (Bq/L)	Country, region	References
1	Ground water	33.97- 49.45	Zurmi Environ, Nigeria	This Work
2	Drinking Water	3.176 - 49.932	Shanono and Bagwai, Nigeria	[02]
3	Ground water	9.15 - 21.21	Idah, Kogi State, Nigeria	[13]
4	Drinking Water	1.70 - 5.83	Babylon- Iraq	[11]
5	Ground water	0.77- 21.23	Zaria, Nigeria	[07]
6	Drinking water	1.2- 9.88	Bam Villages-Iran	[12]
7	Ground water	13.88 - 28.67	Brazil	[14]

CONCLUSION

This work was carried, in order to ascertain the levels of gross alpha/beta radioactivity, Radon222 and their corresponding annual effective doses in ground water around Zurmi gold mines environs. Subsequently, results show that, only five samples for the gross alpha and the entire samples for ^{222}Radon activities had concentrations greater than the safety limit of 0.5 B/q and 11.1 Bq/l respectively. Similarly, the gross beta had activities below the standard contamination of 1.0 Bq/l. However the average annual effective doses due to radon-222, gross alpha and beta activities for the adult, children and infant show a variation in activities that is higher than the recommended limit of 0.1mSv/year [6]. This may be may be due to proximity of the communities to the mining site. However, effect could be mitigated.

REFERENCES

[1] Garba, N. N., Rabiu, N. and Bala, B. M. D. (2012), Preliminary Studies on ^{222}Rn Concentration in Ground Water from Zaria, *Nigeria, Journal of Physical Science*, Vol. 23(1) Pp. 57-60.

[2] Bello, S.,Nasiru, R.,Garba, N.N., Adeyemo,D.J, (2019), Annual effective dose associated with radon, gross alpha and gross beta Radioactivity in drinking water from gold mining area of Shanono and Bagwai Gold Mines, Kano State. Microchemical journal. Pp. 1-4.

[3] Biawas, S., Ferdoas, J., Begon, A., Feroas, N (2015), Study of Gross Alpha and Beta in Environmental Samples. A journal of Scientific Research, vol. 7, Pp:35-44

[4] Abdulkarim, M.S., Abdullahi, M.S., Sadiq.U., Ahmed.M (2018), Determination of gross alpha and gross beta radioactivity in ground water from kaduna metropolis, Duste journal of pure and applied sciences, vol.4 (1), pp.1-2

[5] Garba, N. N., Rabiu, N. and Bala, B. M. D. (2012), Preliminary Studies on ^{222}Rn Concentration in Ground Water from Zaria, *Nigeria, Journal of Physical Science*, Vol. 23(1) Pp. 57-60.

[6] Gado,A.A., Muthukumar, M., Gwani, M., Jonathan, L.A., Kazuga, S (2018), Determination of gross alpha, beta radioactivity in sachet drinking water, research journal of physical sciences, vol 6(3), pp 1-7.

[7] Garba, N. N., Rabiu, N. and Bala, B. M. D. (2012), Preliminary Studies on ^{222}Rn Concentration in Ground Water from Zaria, *Nigeria, Journal of Physical Science*, Vol. 23(1) Pp. 57-60.

[8] ICRP (2008). ICRP Publication 103, Recommendation of the international commission of radiological protection, Annals, Vol. 32 pp. 2-4.

[9] ISO (1992). Water Quality Measurement of Gross Alpha Activity in Non-saline Water. International Standard Organization, (ISO 9696). Pp 8.

[10] Onoja, R.A. (2011). Determination of Natural Radioactivity and Committed Effective Dose Calculation in Borehole Water Supply in Zaria, Nigeria. A PhD Dissertation, Ahmadu Bello University Zaria.

[11] Sadiq, H.L and Jabbar, H.1 (2013), Radon Concentration of Ground Water in Babylon Governorate, *Academic Research International Journal.*Vol. 4(3) pp 260-261.

[13] Aruwa, A., Kassimiu, A.A., Gyuk, P.M., Ahmadu, B., Aniegbu, J.O. (2017), Studies on Radon Concentration in Underground Water of Idah, Nigeria, International journal of research- Granthaalyah, vol.5 (issue 9), pp226-274

[14] Karina, C. M, Sergei, A. P., Valeriy, D., Marilson, R., Janine, N. C andLaercio, B., (2011), studies of radon mitigation in well water by aeration, International Nuclear Atlantic Conference, pp. 1-3.

[15] Gyuk, P. M., Kassimu, A.A., Daniel, I.H., Ahmadu, B., Aruwa, A. and Anaegbu, J. (2017), Analysis of Gross Alpha Radioactivity in Well Water in Some Part of Kaduna South and Environs, Nigeria. *International Journal of Research- Granthaalayah*. Vol. 5, pp. 124-128.