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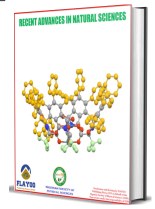

Assessment of activity concentrations of radioactive elements in selected groundwater samples of Kwara State Polytechnic and its environs, North Central Nigeria

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ABSTRACT

A NaI (TI) indicator was used to quantify the activity concentrations level of Uranium (U-238), Thorium (Th-232) & Potassium (K-40) in forty (40) groundwater samples collected across the premises of Kwara state polytechnic and its environs in order to determine the health hazard due intake of drinking water which has its origin from the subsurface. This investigation became necessary as a result of an outbreak of water borne diseases reported by the medical personnels in the clinics around the area. The results obtained from this measurement shows a range of values from 1.01 ± 0.02 to 8.21 ± 1.73, a mean of 3.88 ± 0.609 $Bq.l^{-1}$ for U-238, 0.97 ± 0.01 to 14.81 ± 2.79, a mean value of 7.02 ± 0.99 $Bq.l^{-1}$ Th-232 & 4.44 ± 0.12 to 147.33 ± 6.59 $Bq.l^{-1}$, a mean of 48.08 ± 2.513 $Bq.l^{-1}$ for K-40. The mean of these Radionuclides (U-238, Th-232 and K-40) are higher than the Universal value 10 $Bq.l^{-1}$ for K-40 and 1 $Bq.l^{-1}$ for U-238 and Th-232 as the permissible level for drinking water (United Nations Scientific Committee on Effects of Atomic radiation recommended (UNSCEAR)). In addition, most of the average values of the calculated radiological indices are within the recommended allowable tolerable boundary, although higher values were obtained in some within the study area. These results shows that U-238, Th-232 and K-40 concentrations and radiological parameters in the samples are high and low in values but might take a probabilistic effect on the residents in the near future.

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1. INTRODUCTION

Water (H_20) is life, it is one of the most natural properties on earth with more than seventy percent of it covering the earth surface. Meanwhile about thirty percent of this seventy percent is stored as groundwater while lakes and rivers are responsible for less than half of the water beneath the subsurface [1]. In Nigeria, water is used in homes, livestocks, irrigation purposes companies and industries. In the recent times, increase in population in the urban centers gives rise to the demand for water consumption which is inadequate because of government inability to provide pipe borne water, draining of rivers, pollution of lakes and rivers, etc. In view of this, citizens have resulted to an alternative way of

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getting a clean, consistence and odor free water for their homes and industries. Among the various sources of water, groundwater is categorized as a portable, reliable and consistence sources of water [2].

Asumadu-Sakyi *et al.* [3] described groundwater as water that gathered due to rain, snow etc., which seeps to the ground as a result of gravity. It flows across many areas, plumbed via joints and fractures or fault lines which serves as part ways for its movement via rocks (Igneous and Metamorphic rocks) at the subsurface. Meanwhile during the course of their movement, Natural radioelements interact with water and the rocks forming aquiver which eventually gave rise to dissolution of natural radioactive elements into the system [4]. The dissolutions, spread and occurrence of radionuclide in ground water is aided by factors such geochemical characteristics of rocks and soils hosting aquifer, compressibility, transmissivity, porosity and geochemistry of each radioelement. Meanwhile, the most widely spread radioactive elements are Rn-222, Ra-226, U-238, Th-232 and K-40 while other radioactive elements occur in few quantities due to the fact that majority of them are found to be non-soluble with short half-lives [5]. Some of these Natural radionuclide's decays to polonium through the decay series of Radium (Figure 1). They are present in all rock types and can be found in ground water via leaching or migration from natural radioactive element's rich rocks formation or man-made activities e.g., disposal sites, seepage of pollutant into groundwater bodies from companies, mining activities, abandoned industrial sites, excessive applications of fertilizers on agricultural lands, thermonuclear testing etc.

All the aforementioned factors have contributed to the rise in radioactivity concentrations in groundwater in Nigeria. Although naturally, groundwater can within it self regenerate but the process can take years because of its slow proceeds [1]. Therefore monitoring and assessing groundwater quality based on radionuclides concentration is very important. However, many researchers within Nigeria have reported radionuclides and their health hazards in Air [6, 7], building blocks [8], soil and water samples [1, 9–11] in mining fields [12, 13], and in coaster sandy plain [14] etc., but very little information was reported about radionuclides in groundwater especially within the area. Therefore, the call for this research work in Kwara Polytechnic and its environs becomes necessary since most of the lands within the area were used as either dump-sites or farmland and an outbreak of water borne diseases as reported by some clinics within the area. The results would ascertain whether the estimated Radionuclides concentrations in groundwater could cause any health hazards to the inhabitant or not.

2. MATERIALS AND METHODS

2.1. STUDY AREA

The study area lies in the basement complex rocks of Nigeria and bounded with Lat. 8°31'37.074" to 8°38'12.99 and Long. 4°35'28.41 to 4°38'77.64. Geologically, the area has been described by many researchers [16–21]. Their reports showed that the complex consist of the Schist belt, Porphyritic older granites Migmatite gneiss complex and Miscellaneous rock types. The study area consists of close to sixty percent of rocks that make up Migmatite-Gneioss-Quatzite Complex. The rocks found are

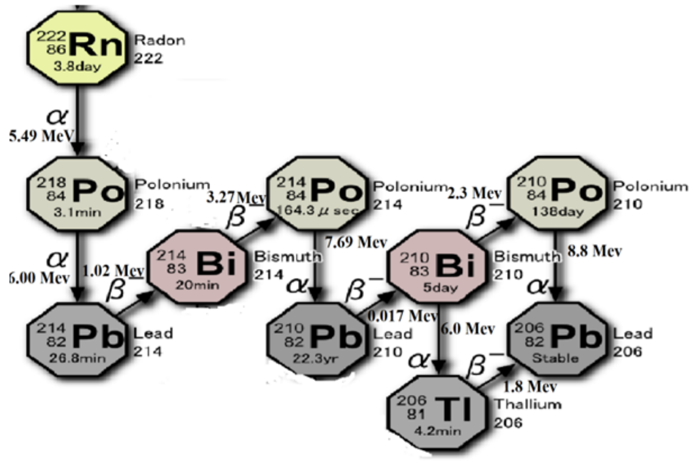

Figure 1. Decay series from Ra-222 to Pb-206 [15].

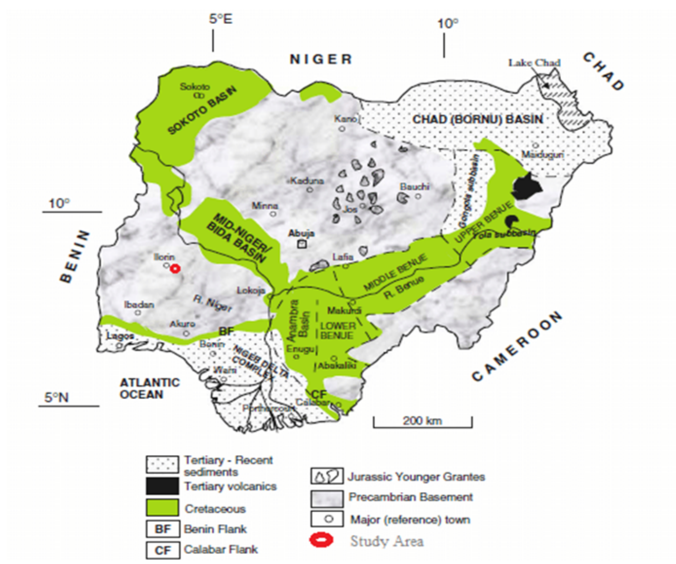

Figure 2. Map of Nigeria displaying geology and location of the area of study [20].

igneous and metamorphic intrusive formations. Schist belt are in abundance in the middle part and localized to be found in the southwest of Nigeria make up of younger metasediments cut across the pre-existing rock of the area as shown on the geological map (Figure 2). The area has a vegetation which is mainly of guinea savanna type with a topography of crests and troughs which is as a result of erosion.

In order to assess concentrations of radioactive elements in ground water samples of Kwara State Polytechnic and its environs, forty samples labeled Grdw 1 to Grdw 40 were randomly collected from wells (depth values ranges from 12 m to 20 m). The sample area was cautiously selected in order to denote places where students and other occupants' inhabitants are performing numerous events. The coordinates of each sample area were logged with the help of a handheld Germaine GPS (Table 1). These samples were packaged in an air tight Marinelli cylindrical beaker and individual beaker is wash away with a detergent in liquid form, oven-dried, rubbed with acetone and later oven-dried [13].

These water samples were sealed with a tape made up of an adhesive substance and stored in a cylindrical beaker of Marinelli type so that Radon gas will not escape. A forty days secular radioactive equilibrium was observed on the samples before taken it to the central research lab of *Ladoke Akintola University of Technology, Ogbomosho* where a NaI (TI) gamma spectroscopy indicator was used. The indicator employed for the detection of these elements is made up of a 3inch × 3inch NaI (Tl) indicator, an invention of a company in the USA named Princeton Gamma Technology. The mode of operations of this detector can be found in the work of Orosun *et al.* [22]. The amount of radioactivity present in the peak area of spectrum as it relates to the efficiency of the full peak energy was chosen and given by the expression:

$$\varepsilon = \frac{C_{net}}{A \times P_\gamma \times T}, \tag{1}$$

where C_{net}, P_γ, T, A are highest amount for individual radioactive element, total probability gamma emission of obtained radio elements, time acquired and concentrations of the radioactive elements present in the source.

Before the measuring the samples, a container which is empty was counted for 36000 s in order to obtain distribution of gamma radiation in the background. In order to identify individual radioactive element present in the sample, the activity concentrations A, was obtained using the expression:

$$A = \frac{C_{net}}{\gamma \times \varepsilon(E_\gamma) \times t \times M_s}, \tag{2}$$

where C_{net} equals net count rate a corresponding photopeak, $\varepsilon(E_\gamma)$ is the efficiency indicator at the specified gamma energy (E_γ), γ = absolute gamma intensity, t equal counting time which is 36000s & M_s is mass sample measured in kilogram.

The measured activity concentrations obtained for these radioactive elements will be used to evaluate the radio hazard indices.

2.2. THE RADIOLOGICAL PARAMETERS

1. The Radium activity equivalent (R a_{eq}) estimate the hazards caused by primordial natural radio elements (U-238, Th-232 and K-40) and the expression for Ra_{eq} ($Bq.l^{-1}$) is given as [23, 24].

$$Ra_{eq} = C_u + 1.43C_{Th} + 0.077C_k, \tag{3}$$

where C_u, C_{Th}, *and* C_k are concentrations of U-238, Th-232 and K-40 measured in $Bq.l^{-1}$ and the world extreme permissible limit of Ra_{eq} is 370 Bql^{-1} [25].

2. The absorb dose rate is defined as the amount of energy reported for each mass of the exposed substance and it can be expressed as [23]

$$D(nGyh^{-1}) = 0.462C_u + 0.604\ C_{Th} + 0.041C_k, \tag{4}$$

where C_u, C_{Th}, and C_k concentrations of U-238, Th-232 and K-40 measured in $Bq.l^{-1}$ and the world extreme permissible limit of $55nGyh^{-1}$ [25].

3. The external and internal hazard guides are to reduce the amount of dose allowable which are equal to limit of 1 $mSvy^{-1}$ (Valentin, 2007). They are expressed as [24, 27]

$$H_{ex} = \left(\frac{C_u}{740}\right) + \left(\frac{C_{Th}}{520}\right) + \left(\frac{C_k}{9628}\right) \le 1, \tag{5a}$$

$$H_{in} = \left(\frac{C_u}{185}\right) + \left(\frac{C_{Th}}{259}\right) + \left(\frac{C_k}{4810}\right) \le 1, \tag{5b}$$

where C_u, C_{Th}, *and* C_k are activity concentrations of U-238, Th^{-232} and K^{-40} measured in $Bq.l^{-1}$.

4. The Annual Gonadal Dose Equivalent (AGDE) quantifies the radiological risk directly from the natural radionuclides which affect the bone surface, the gonads and the active bone marrow (UNSCEAR, 2008). The expression of AGDE is given as [28, 29].

$$AGDE(\mu Svyr^{-1}) = 3.09C_u + 4.18\ C_{Th} + 0.314C_k, \tag{6}$$

where C_u, C_{Th}, *and* C_k are concentrations of U-238, Th-232 and K-40 measured in Bql^{-1} and the world extreme permissible limit of 0.30 μSvy^{-1} [25].

5. Gamma Index gives information about the hazards resulting from radiation from gamma sources which has radionuclides specified sample. The expression for the gamma index is given as [30].

$$I_\gamma = \left(\frac{C_u}{150}\right) + \left(\frac{C_{Th}}{100}\right) + \left(\frac{C_k}{1500}\right) \le 1, \tag{7}$$

where C_u, C_{Th}, *and* C_k are activity concentrations of U-238, Th^{-232} and K-40 measured in $Bq.l^{-1}$.

6. The total annual effective doses owing to ingested Radio elements (TAED $_{ingested}$). TAED owing to injection of U-238, Th-232 and K-40 in groundwater consumed by different age groups (i.e., infant, children of different ages and adults) in the study area is given as

$$TAED_{ingested} = \sum (d_i * C_i) * 365 * C.F), \tag{8}$$

where d_i is the daily intake of water per individual. for instance, an infant will consume 1/2 liter of water per day, children will drink one ltr of water/day while adults will drink two ltrs of water/day [31, 32]. The C_i is concentration of individual radio element in groundwater sample and C.F. is the dose conversion factors for people in the environment. This dose conversion factor is shown in Table 1 [25, 32, 33].

7. The excess lifetime cancer risk (ELCR) is used to obtain a potential indicator for lifetime cancer risk which can occur as a result of long term natural radionuclides in groundwater consumed due to injection. The expression is given as [11, 29].

$$ELCR = TAEDE_{ingested} \times DL \times RF, \tag{9}$$

where TAED $_{injected}$ is the TAEDE (Eq. (8)), Duration of Life is DL which is taken to be seventy years [29] and Risk factor is the R.F. which is 0.05 S v^{-1} was used.

Table 1. The dose conversion factor for injected radionuclides of members within the environment of different age groups

Radio nuclides (Bql^{-1})	Infants (I) ($SvBq^{-1}$)	1 yr. ($SvBq^{-1}$)	5 yrs. ($SvBq^{-1}$)	10 yrs. ($SvBq^{-1}$)	15 yrs. ($SvBq^{-1}$)	Adults ($SvBq^{-1}$)
Uranium-238	0.00000014	0.00000012	0.00000008	0.000000068	0.000000067	0.000000045
Thorium-232	0.0000016	0.00000045	0.00000035	0.00000029	0.00000025	0.00000023
Potassium-40	0.000000052	0.000000042	0.00000022	0.000000013	0.0000000076	0.0000000062

Table 2. Activity concentrations of groundwater samples.

S/N	Latitude	Longitude	Samples	K-40 Bq^{-1} ±	errors	U-238 Bql^{-1} ±	errors	Th-232 Bql^{-1} ±	errors
1.	N8°33’7.878"	E4°38’7.764"	Grdw1	56.27	4.05	3.89	0.56	8.91	1.65
2	N8°33’7.022"	E4°38’7.524"	Grdw2	4.67	1.41	5.72	0.69	10.9	1.19
3	N8°33’6.78	E4°38’5.94"	Grdw3	7.29	2.18	3.27	1.12	6.52	0.34
4	N8°33’6.954	E4°38’2.676"	Grdw4	18.2	1.29	2.53	0.29	4.61	0.16
5	N8°32’11.484"	E4°37’49.5"	Grdw5	7.36	0.43	6.88	0.12	2.76	0.12
6	N8°32’10.668"	E4°37’48.72"	Grdw6	6.91	0.12	5.84	0.19	3.57	0.11
7	N8°32’10.686	E4°37’46.74	Grdw7	8.66	1.16	1.46	0.12	0.97	0.01
8	N8°31’37.074"	E4°36’5.166"	Grdw8	25.41	2.56	4.74	0.4	7.35	1.36
9	N8°31’41.364"	E4°36’4.224"	Grdw9	32.27	2.04	2.89	0.64	3.1	0.44
10	N8°31’42.192"	E4°36’3.27"	Grdw10	86.05	3.41	4.51	0.8	10.89	1.59
11	N8°31’43.914"	E4°36’3.282"	Grdw11	17.29	0.12	3.28	1.64	8.35	1.39
12	N8°31’45.492"	E4°36’3.21	Grdw12	57.33	2.55	3.47	0.71	4.37	0.54
13	8°31’47.1"	E4°36’3.192"	Grdw13	64.44	5.38	4.87	0.83	11.01	1.6
14	N8°32’27.396"	E4°36’17.028"	Grdw14	21.41	2.27	2.13	0.59	6.86	1.38
15	N8°33’46.944"	E4°36’28.226"	Grdw15	147.33	3.67	6.14	0.89	14.79	1.78
16	N8°35’5.712"	E4°36’1.626	Grdw16	12.59	1.86	3.76	0.13	5.72	0.36
17	N8°35’7.704"	E4°36’0.24"	Grdw17	34.96	2.85	8.21	0.28	4.51	0.28
18	N8°37’29.532"	E4°35’28.41"	Grdw18	87.42	6.54	4.87	0.59	4.63	0.52
19	N8°38’12.99"	E4°35’35.802"	Grdw19	70.02	3.15	3.69	0.68	4.86	0.75
20	N8°33’32.376"	E4°36’49.368"	Grdw20	131.67	6.59	4.06	0.65	9.44	1.03
21	N8°31’50.376"	E4°36’15.294"	Grdw21	78.36	3.12	2.49	0.28	11.49	1.4
22	N8°32’31.602"	E4°38’2.052"	Grdw22	21.49	0.21	2.54	0.02	1.82	0.01
23	N8°32’26.316"	E4°38’2.946	Grdw23	49.84	0.21	1.53	0.23	2.51	0.14
24	N8°32’27.12"	E4°38’4.212"	Grdw24	42.8	3	2.15	0.12	4.78	0.11
25	N8°32’26.538"	E4°38’3.984"	Grdw25	82.36	3.36	4.94	0.71	13.79	2.56
26	N8°32’26.58"	E4°38’2.388"	Grdw26	27.41	2.06	3.47	0.75	7.79	1.89
27	N8°32’25.05"	E4°38’2.568"	Grdw27	17.4	2.51	6.48	1.26	14.81	2.79
28	N8°32’24.3"	E4°38’3.534"	Grdw28	4.44	0.26	1.64	0.19	3.47	0.75
29	N8°32’24.034"	E4°38’4.89"	Grdw29	13.29	1.82	4.61	1.73	9.89	0.95
30	N8°32’20.838"	E4°38’3.378"	Grdw30	84.44	3.38	1.01	1.6	4.87	0.83
31	N8°32’20.142"	E4°37’59.982"	Grdw31	10.41	1.27	1.04	0.19	2.13	0.59
32	N8°32’20.652"	E4°37’59.406"	Grdw32	73.02	4.13	3.34	0.77	8.63	1.75
33	N8°32’19.992"	E4°37’59.826"	Grdw33	103.61	3.59	5.89	0.67	9.48	1.77
34	N8°32’19.794"	E4°37’56.406"	Grdw34	88.36	3.32	2.8	0.6	13.1	1.68
35	N8°32’16.584"	E4°37’55.602"	Grdw35	21.39	0.21	5.5	0.29	1.55	0.07
36	N8°32’16.626"	E4°37’55.482"	Grdw36	69.87	2.96	3.31	0.19	4.44	0.98
37	N8°32’15.888"	E4°37’57.282"	Grdw37	23.33	3.02	2.46	0.61	5.49	1.08
38	N8°32’16.89"	E4°37’56.664"	Grdw38	60.17	2.59	4.77	0.79	9.02	1.39
39	N8°32’17.34"	E4°37’59.418"	Grdw39	117.4	3.82	6.99	0.95	14.29	1.73
40	N8°32’18.57"	E4°38’0.36"	Grdw40	36.27	2.05	2.14	0.51	3.19	0.79
			Min	4.44	0.12	1.01	0.02	0.97	0.01
			Max	147.33	6.59	8.21	1.73	14.81	2.79
			Average	48.08025	2.513	3.88275	0.6095	7.0165	0.9965

3. RESULTS AND DISCUSSION

Table 2 shows concentrations of natural radio element in the forty samples obtained across the area of study. These samples were

Table 3. Comparison of Activity concentrations of groundwater in with other areas of the World.

Case study	Countries	K-40 (Bql^{-1})	U-238 (Bql^{-1})	Th-232 (Bql^{-1})	References
Packaged water	Nigeria	2.17 – 8.55	0.08 – 0.63	0.06 – 3.57	[31]
Hand dug Well	Nigeria	1.45 – 31.93	2.85 – 25.80	0.57 – 7.11	[38]
Groundwater	Egypt	9.70 – 23.0	0.97 – 1.60	0.21 – 1.1	[39]
Groundwater	Namibia	16.91 – 20.92	1.21 – 2.21	0.054 – 0.039	[23]
Groundwater	Nigeria	8.80 – 30.77	0.33 – 1.04	0.49 – 1.36	[11]
Well	Egypt	1.1 – 23.0	1.6 – 11.1	0.21 – 1.0	[39]
Surface Water	Malaysia	152	-2.86	3.78	[40]

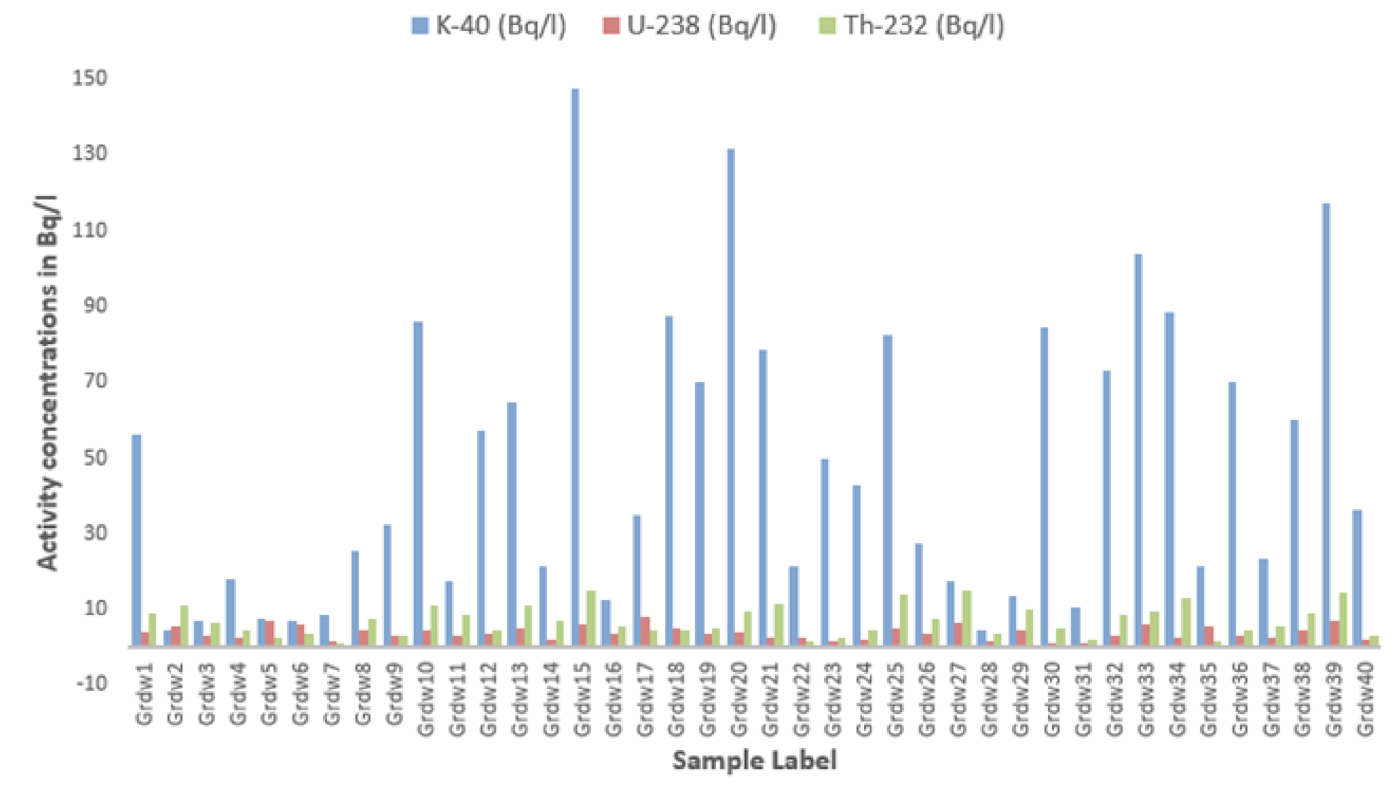

Figure 3. Concentrations of radionuclides in some selected groundwater sample within Kwara Poly and its Environs.

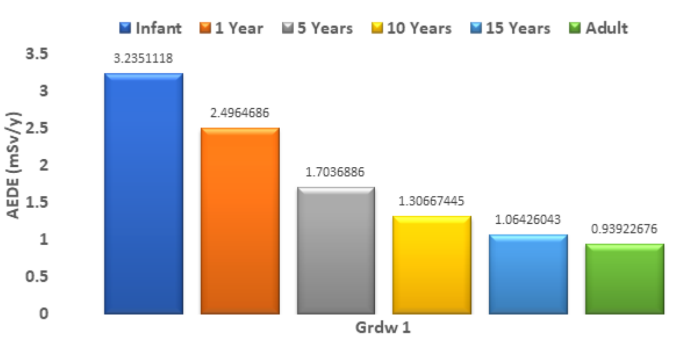

Figure 4. Average TAEDE for the inhabitants of various age group in sample Grdw1

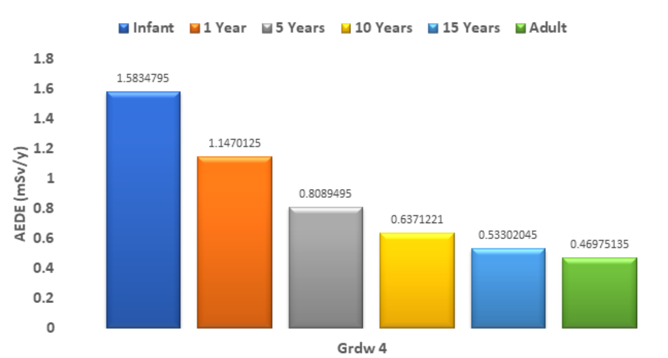

Figure 5. Average TAEDE for the inhabitants of various age group in sample Grdw4

analyzed in the laboratory using NaI (TI) detector in order to acquire the concentrations of non-decay series potassium-40 and natural decay chains of Uranium-238 and Thorium-232. These results are plotted in Figure 3 and they reveal a range of 4.44 ± 0.12 to 147 ± 6.59 $Bq.l^{-1}$, an average value of 48.08 ± 2.51 $Bq.l^{-1}$, for Potassium-40, 1.01 ± 0.02 to 8.21 ± 1.73 $Bq.l^{-1}$ with an average value of 3.88 ± 0.61 $Bq.l^{-1}$ for Uranium-238 & 0.97

Table 4. Radiological Parameters indices of radionuclides obtained from the samples.

Sample No.	Raeq (Bq.l^{-1})	D (nG/h)	H ext (Bq.l^{-1})	H int (Bq.l^{-1})	AGED (μSvy)$^{-1}$	Gamma Index
Grdw1	20.94703	9.525279	0.028236	0.067127	66.93268	0.152546667
Grdw2	21.65066	9.420979	0.029176	0.073975	64.70318	0.150246667
Grdw3	13.14505	5.752813	0.017715	0.044365	39.64696	0.09186
Grdw4	10.51571	4.71224	0.014175	0.035259	32.8023	0.0751
Grdw5	11.38901	5.152512	0.015369	0.049376	35.10704	0.078373333
Grdw6	11.47154	5.142507	0.015475	0.046788	35.13794	0.07924
Grdw7	3.511868	1.621522	0.004738	0.013437	11.28524	0.025206667
Grdw8	17.19462	7.688877	0.023179	0.059283	53.34834	0.12204
Grdw9	9.800879	4.553239	0.013219	0.0343	32.02088	0.07178
Grdw10	26.68637	12.249465	0.035974	0.084315	86.4758	0.196333333
Grdw11	16.53857	7.279753	0.022286	0.053564	50.46726	0.116893333
Grdw12	14.12286	6.633281	0.019048	0.047548	46.99052	0.105053333
Grdw13	25.55549	11.587128	0.034447	0.082231	81.30426	0.185526667
Grdw14	13.57692	6.020297	0.018294	0.042451	41.97924	0.097073333
Grdw15	38.60165	17.913501	0.052042	0.120923	127.05642	0.287053333
Grdw16	12.89989	5.717003	0.017389	0.045027	39.48126	0.09066
Grdw17	17.34209	7.974892	0.023399	0.06906	55.19814	0.12314
Grdw18	18.2089	8.691874	0.024565	0.062375	61.85158	0.137046667
Grdw19	16.01901	7.560054	0.021605	0.053268	53.70318	0.11988
Grdw20	27.67418	13.068119	0.037316	0.085768	93.34898	0.209246667
Grdw21	24.93198	11.357952	0.0336	0.074113	80.32734	0.18374
Grdw22	6.793077	3.168893	0.009164	0.025225	22.20406	0.04946
Grdw23	8.94956	4.301228	0.012071	0.028323	30.86926	0.068526667
Grdw24	12.27088	5.66518	0.016543	0.038975	40.0631	0.090666667
Grdw25	30.97538	14.045852	0.041749	0.097069	98.76784	0.22574
Grdw26	16.70703	7.451297	0.022517	0.054533	51.89124	0.119306667
Grdw27	28.9756	12.66458	0.039045	0.095826	87.3926	0.2029
Grdw28	6.938681	3.038708	0.00935	0.023186	20.96636	0.048593333
Grdw29	19.76088	8.657573	0.026629	0.065867	59.75816	0.138493333
Grdw30	14.46253	6.929248	0.019501	0.041818	49.99166	0.111726667
Grdw31	4.883626	2.201097	0.006583	0.01601	15.38574	0.035173333
Grdw32	21.28549	9.800534	0.028694	0.066555	69.32228	0.157246667
Grdw33	27.40286	12.767637	0.036952	0.089981	90.36004	0.20314
Grdw34	28.31121	12.890612	0.038153	0.084084	91.15504	0.208573333
Grdw35	9.35967	4.369163	0.012635	0.040161	30.19046	0.066426667
Grdw36	15.02747	7.124559	0.020268	0.049561	50.72628	0.113046667
Grdw37	12.09747	5.425341	0.016305	0.039345	37.87522	0.086853333
Grdw38	22.28418	10.160909	0.030042	0.073119	71.33628	0.162113333
Grdw39	36.43505	16.75612	0.04912	0.117365	118.1949	0.267766667
Grdw40	9.487143	4.427899	0.012794	0.031425	31.33558	0.070346667
Min	**3.511868**	**1.621522**	**0.004738**	**0.013437**	**11.28524**	**0.025206667**
Max	**38.60165**	**17.913501**	**0.052042**	**0.120923**	**127.05642**	**0.287053333**
Average	**17.6048**	**8.03674293**	**0.023734**	**0.058074**	**56.423866**	**0.1281035**

± 0.01 to 14.81 ± 2.97 Bq.l^{-1}, average value of 7.01 ± 0.99 Bq.l^{-1} for Thorium-232 respectively.

The result of this activity concentrations varies from one groundwater sample to the other. These variations in their concentrations may be attributed to the huge adjustments in the rare-earth elements, chemical and mineral possessions of the groundwater that occurs in different host rocks [23]. For instance, granite, gneiss, basalt rocks have radionuclides values ranging from 1.24 to 75.34 BqL^{-1} for Uranium-238, 8.12 to 564.34 BqL^{-1} for Thorium-232 while Potassium-40 ranges from 1.34 to 430 BqL^{-1} [34, 35]. Also observed from the result is trends of these radionuclides which shows that Potassium-40 > Thorium-232 > Uranium-238. This demonstrate that value of U-238 concentration is lower than the value of Thorium-232 and Potassium-40. This is because Uranium-238 is soluble in water and can leached be before deposition [35]. Uranium-238 has its highest value in Grdw sample 17 while the lowest value is found in Grdw sample 30. This higher value of Uranium-238 concentrations in Grdw sample 17 may be due to the presence of Acidic igneous rocks that are soluble and has its mobility in water.

Table 5. AEDE (mSv/yr) for all group of Inhabitant

Sample ID	AEDE (mSv/yr) for all groups						
	Infant (I)	One yr.	Five yrs.	Ten yrs.	Fifteen yrs.	Adults (A)	ELCR×10^{-3}
Grdw1	3.235112	2.496469	1.703689	1.306674	1.06426	0.939227	3.28729366
Grdw2	3.373264	2.112452	1.596999	1.317895	1.147462	1.019574	3.568509735
Grdw3	2.056571	1.325892	0.986953	0.805894	0.69514	0.617561	2.16146357
Grdw4	1.58348	1.147013	0.80895	0.637122	0.53302	0.469751	1.644129725
Grdw5	1.05155	0.867503	0.612587	0.497831	0.440517	0.361362	1.26476588
Grdw6	1.257228	0.948095	0.682083	0.555621	0.487748	0.411261	1.439412905
Grdw7	0.402726	0.356028	0.236089	0.180003	0.14824	0.12501	0.43753353
Grdw8	2.508448	1.804385	1.281413	1.016215	0.857092	0.75239	2.633364405
Grdw9	1.285282	1.130456	0.739541	0.552986	0.443067	0.38074	1.33259091
Grdw10	4.111725	3.305367	2.213871	1.672952	1.342707	1.183023	4.1405819
Grdw11	2.686086	1.780207	1.301327	1.047298	0.890112	0.793984	2.778943195
Grdw12	1.90876	1.748627	1.119951	0.820721	0.642655	0.553594	1.93757914
Grdw13	3.950884	3.009564	2.066185	1.59205	1.302515	1.150107	4.025374395
Grdw14	2.260722	1.548264	1.110483	0.880588	0.737455	0.659333	2.30766578
Grdw15	5.873719	4.956758	3.25177	2.416997	1.908435	1.675878	5.865572265
Grdw16	1.885787	1.297203	0.94162	0.758525	0.648825	0.570443	1.996551095
Grdw17	1.858456	1.636302	1.096613	0.847041	0.709292	0.592578	2.074023805
Grdw18	2.306004	2.313932	1.435669	1.025767	0.784086	0.66651	2.332783985
Grdw19	2.177889	2.033284	1.290874	0.938262	0.727949	0.627061	2.194711785
Grdw20	4.109761	3.746849	2.381822	1.724767	1.32594	1.157143	4.049999485
Grdw21	4.162336	3.197553	2.169786	1.649837	1.326726	1.182812	4.139843505
Grdw22	0.800277	0.739629	0.479238	0.35766	0.287804	0.24314	0.850991295
Grdw23	1.244993	1.243329	0.765544	0.540149	0.40471	0.348633	1.220214345
Grdw24	1.856865	1.535409	1.017109	0.762412	0.60748	0.533451	1.867079025
Grdw25	4.934493	3.743958	2.567271	1.973081	1.607612	1.425191	4.98816738
Grdw26	2.623459	1.851689	1.316599	1.040757	0.871732	0.772994	2.70547928
Grdw27	4.65521	2.983109	2.220916	1.811035	1.558149	1.38911	4.86188395
Grdw28	1.097278	0.709845	0.526834	0.429072	0.36906	0.328291	1.14901927
Grdw29	3.131788	2.030086	1.504778	1.224338	1.052067	0.93606	3.27621007
Grdw30	2.249181	2.138601	1.329688	0.941226	0.703324	0.616513	2.157797145
Grdw31	0.747323	0.55499	0.386068	0.300669	0.248673	0.219453	0.768086655
Grdw32	3.298257	2.683166	1.786361	1.342864	1.071725	0.944592	3.30607291
Grdw33	3.901908	3.403413	2.215046	1.641277	1.296504	1.127059	3.94470538
Grdw34	4.735276	3.628874	2.464816	1.875399	1.50896	1.345694	4.70992788
Grdw35	0.796116	0.823396	0.530374	0.402073	0.335276	0.268866	0.941029495
Grdw36	2.044117	1.945355	1.224918	0.883661	0.679915	0.585221	2.04827196
Grdw37	1.887335	1.367129	0.960519	0.752875	0.625839	0.554087	1.939303765
Grdw38	3.326727	2.612867	1.774754	1.358665	1.106637	0.971741	3.40109336
Grdw39	5.465401	4.453037	2.972378	2.243151	1.800571	1.580132	5.530463575
Grdw40	1.330359	1.173709	0.761259	0.562877	0.444034	0.385029	1.347601535
Min	**0.402726**	**0.356028**	**0.236089**	**0.180003**	**0.14824**	**0.12501**	**0.43753353**
Max	**5.873719**	**4.956758**	**3.25177**	**2.416997**	**1.908435**	**1.675878**	**5.865572265**
Average	**2.604304**	**2.059595**	**1.395819**	**1.067207**	**0.868583**	**0.761615**	**2.665652323**

Thorium-232 was found to have higher value of concentrations in almost all places within the study area excluding sample site 5, 6, 17, 18 and 35. The higher values of Thorium-232 in all other sample site except Grdw 5, 6, 17, 18 and 35 may be due to insolubility nature of Thorium in water and its ability to move geochemically is very slow [35] and lastly on radionuclides, is Potassium-40 which has a higher value than other radionuclides in all the Grdw samples sites which as highest value in site 15, followed by 20, 39 respectively and its lowest value was found in sample site 28. This higher value Potassium-40 may be due to its ability to dissolve in water nonetheless doesn't accrue to the body system. Therefore, it remains stable at a level that is autonomous of its intake [36].

From these results, it can be deduced that all samples within

Figure 6. Average TAEDE for the inhabitants of various age group in sample Grdw7

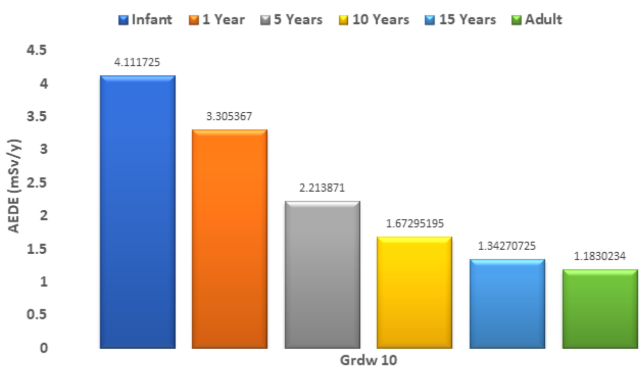

Figure 7. Average TAEDE for the inhabitants of various age group in sample Grdw10

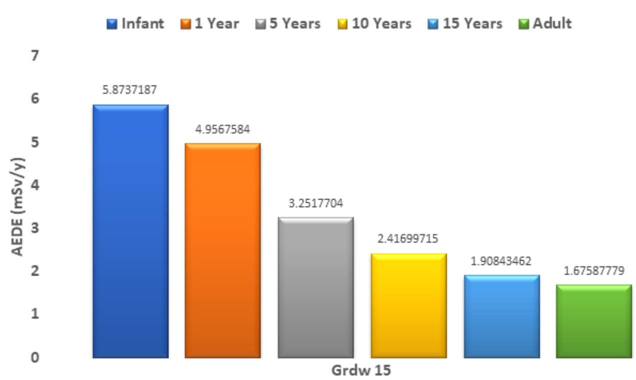

Figure 8. Average TAEDE for the inhabitants of various age group in sample Grdw15

the area of study exceed the Universal global limit of 10 Bql^{-1} for Potassium-40 and 1 Bql^{-1} for Thorium-232 and Uranium-238 [13, 32, 37] as the permissible level for drinking water. It is evident from this work that the rock type present in this area is acidic and basic in nature which are of intrusive and metamorphic formations. The results obtained from this research work is in agreement with other work earlier carried out within the region [31, 35, 38]. Meanwhile Table 3 shows comparison with results obtained within Nigeria.

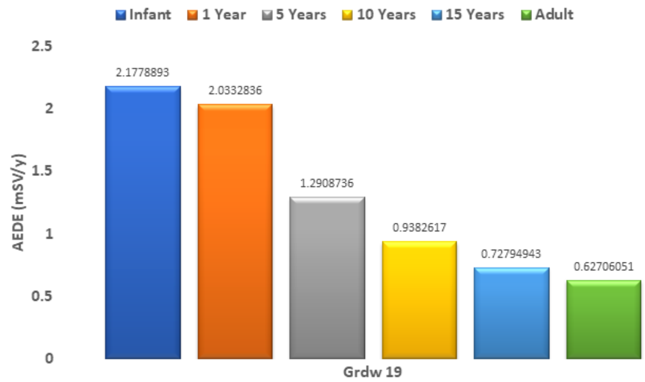

Figure 9. Average TAEDE for the inhabitants of various age group in sample Grdw19

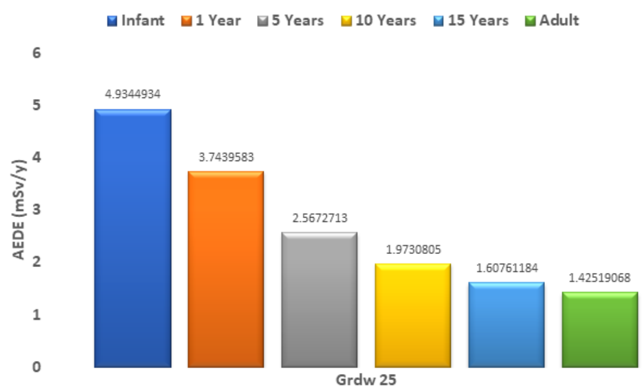

Figure 10. Average TAEDE for the inhabitants of various age group in sample Grdw25

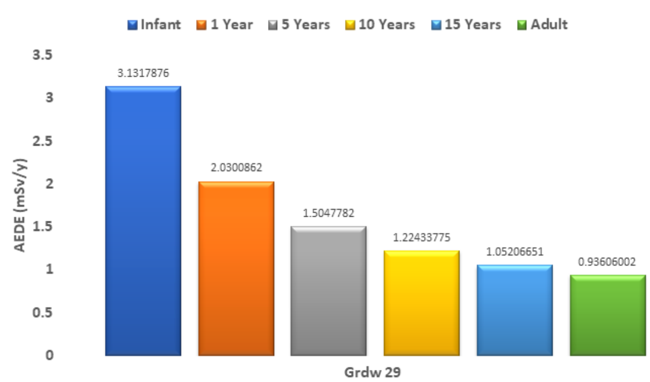

Figure 11. Average TAEDE for the inhabitants of various age group in sample Grdw29

4. THE RADIOLOGICAL PARAMETERS (TRP)

The Radiological parameters considered in this work include:

1. Radium equivalence (Ra_{eq}) that is used to define the yield of gamma from the contributions of U-238, K-40 and Th-232 of the groundwater samples of area of study was achieved by means of expression 3.0. The obtained values range from 3.51 Bql^{-1} in sample Grdw 7 to 38.60 Bql^{-1} in sample Grdw 14 through a mean value of 17.60 $Bq.l^{-1}$ (Table 4). The mean cost obtained is less than 370 Bql^{-1} recommended by

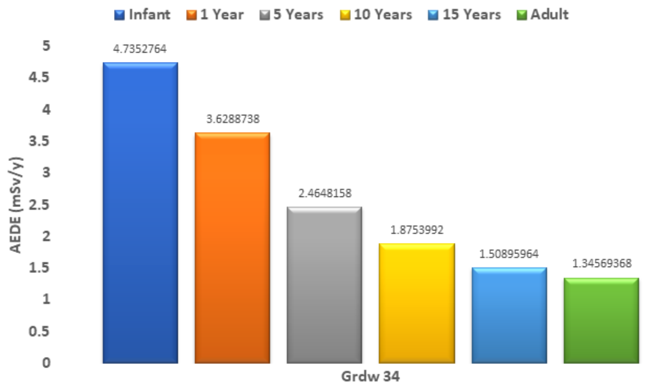

Figure 12. Average TAEDE for the inhabitants of various age group in sample Grdw34

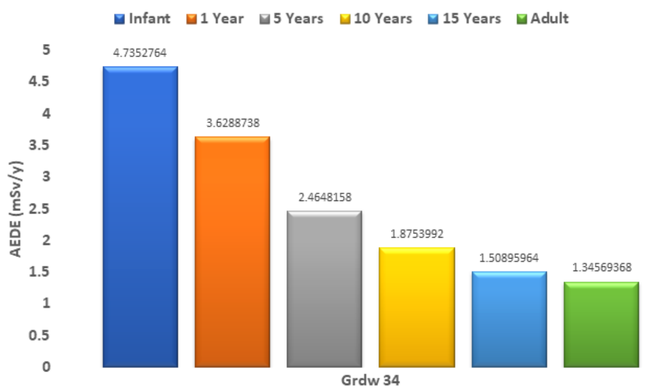

Figure 13. Average TAEDE for the inhabitants of various age group in sample Grdw39

[25, 30].

2. D measured in (nGy/h) was calculated by means of expression 4.0. The obtained value ranges from 1.62 in sample Grdw 7 to 17.91 nGy/h in sample Grdw 15 through a mean value of 8.03 nGyh^{-1}. This mean value is lowered than the recommended value of 57 nGyh^{-1} [25].
3. For the assessment of health effects of the occupant's exposure due to ionizing radiation emanating from the subsurface of the earth that contains U-238, Th-232 and K-40 radiation, hazard indices from internal and external sources were calculated using Eqs. (5a) and (5b). The calculated values of external indices ranges from 0.0047 in Grdw 7 to 0.0520 in Grdw 15 with a mean value of 0.0237 while the internal indices ranging between 0.0134 in Grdw 7 to 0.12 in Grdw 15 with a mean value of 0.058. The mean value obtained are lower than the World maximum value of 1 [25]. This reveals that there are no risk which can emanate from the exposure of residents due to radiological indices.
4. The AGEDE was calculated using Eq. (6), the result ranges from 11.28 Sv/y in sample Grdw 7 to 127.56 Sv/y in sample Grdw 15 with a mean value of 56.42 Svy^{-1}. This mean value of AGEDE is lower than the approved World limit of 10^3 Svy^{-1} [25, 29]. Investigating the AGEDE became necessary because of its yearly equivalent dose received by the reproductive population's organ and since when sensitive part of the body like the gonad is exposed to radiation, it can lead to genetic mutation of the cells or untimely death [22]. However, the average value obtained due to AGEDE reveals that the inhabitants are safe from genetic mutation of cells.
5. The external gamma index was obtained by means of expression 6.0 and the result obtained reveals that sample Grdw-7 has a minimum value of 0.035 while Grdw-15 has a maximum value of 0.28 with a mean value of 0.128. The mean value obtained is less than 1 as approved by World limit [25].
6. Meanwhile, TAEDE which is as a result of injected radioactive element (U-238, Th-232, K-40) in groundwater sample were evaluated based on the classification of inhabitant in the area (Infant, Children, and Adults) using Eq. (8). The obtained result is shown in Table 5 and the bar chat plots are displayed in Figures 4–13. It can be deduced from the table that the lowest AEDE was revealed in sample Grdw-7. It shows that infant is given as 0.4025 mSvy^{-1}, 1 year old is given as 0.356 mSv/y, 5 yrs old is given as 0.236 mSv/y, 10 yrs old is given as 0.180 mSv/y, 15 yrs is 0.49 mSv/y and Adult has a value of 0.125 mSv/y. Sample Grdw-15 has the highest value of dose equivalence with the followings: (Infant is 5.87 mSv/y, 1 year is 4.956, 5 years is 3.25 mSv/y, 10 years is 2.42, 15 years is 1.908 mSv/y and lastly Adult is 1.68 mSv/y. also noticeable from the plots (Figures 4-13) is the trends, that is (Infants > 1 year> 5 years > 15 years > Adults) which is the same in all samples considered. This trend is an attestation to the fact that the lower the age class, the more prone to ionizing radiation when water of those liters of water are consumed daily [31]. In addition, all the groundwater samples from this area except Grdw samples 7, 22, 31 and 35 have higher AEDE value for ingested radionuclide in the class of age group than the approved value of 1 mSvy^{-1}. This means that Grdw sample 7, 22, 31 and 35 are save for all categories of age groups in the area which is just 10% of the samples while 90% of the Grdw sample are not safe for consumption since the AEDE are bigger than the approved value of 1 mSvy^{-1}.
7. Lastly, the ELCR obtained using expression 10.0 enumerated in Table 5 and plotted in Figure 14. The values shows that ELCR ranges from 0.44 x 10^{-3} as in Grdw 7 sample to 5.86×10^{-3} for Grdw 15 with an average value of 2.66×10^{-3}. The ELCR obtained from this study is due to ingested radionuclides in the consumed groundwater based on different age groups. This also shows that all groundwater samples are higher than the approved World mean bound of 0.00002. This result is in agreement with the work carried out in package drinking water within Ilorin and Ogbomosho [31]. It can be deduced that residents in this area are prone to diseases such as cataracts, skin cancer and asthma. It also implies that the probability of residents of this area will have cancer over lifetime based on 70 years of age as the average span of the inhabitant as a whole should be given a proper attention. In view of the above, this research work call for investigation of other groundwater samples in the area while the results obtained in this work should serve as a base line for other radionuclides investigations.

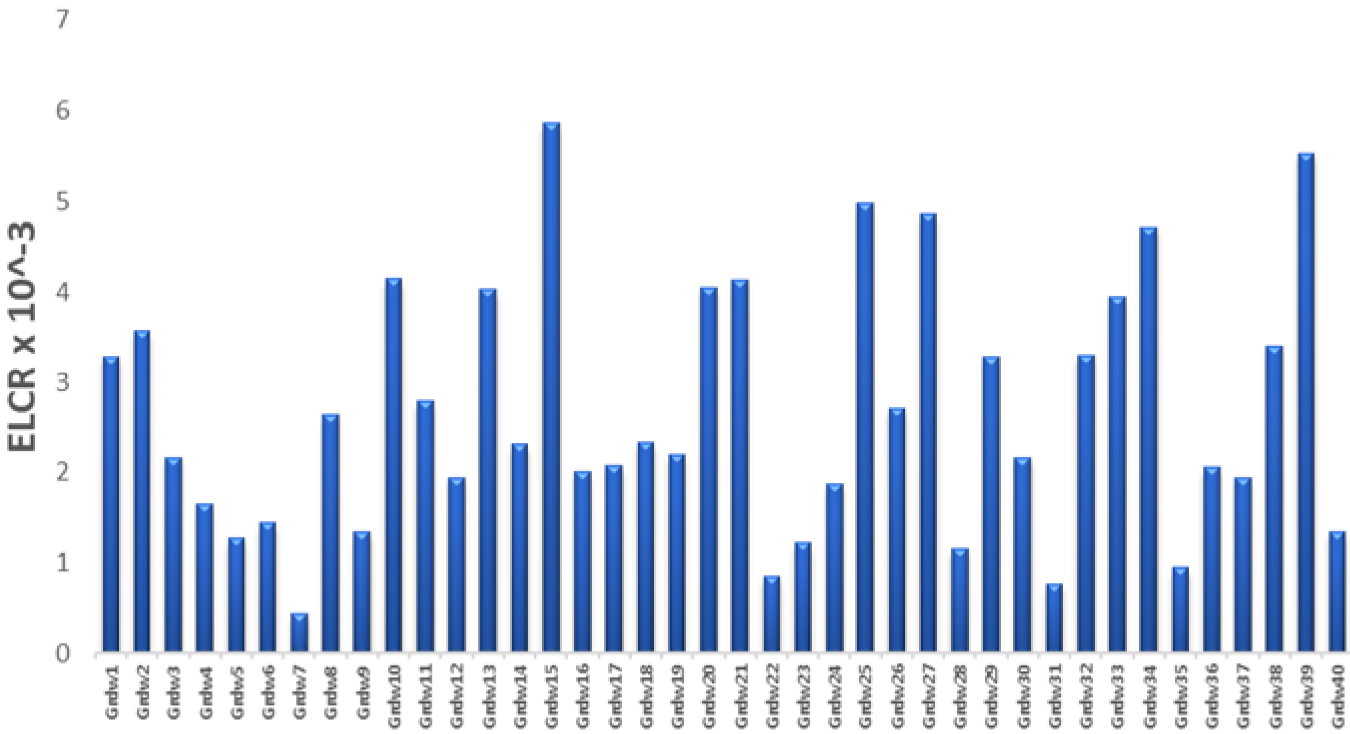

Figure 14. Average ELCR for Adult in the Grdw samples within the study area

5. CONCLUSION

We have analyzed and obtained concentration of radioactive elements in forty groundwater sample of different locations within Kwara poly and its environs by means of spectrometric method. The average activity concentrations of these radioactive elements are above the recommended Universal 10 Bql^{-1} for K-40 and 1 Bql^{-1} for U-238 and Th-232 respectively. The trends of these radionuclides shows that U-238 < Th-232 < K-40 which is an indication that value Uranium-238 concentration is lower than the that of Th-232 and K-40. It is evident from this work that because of higher mean values of these radionuclides, the rock formation in this area is acidic and basic in nature which are of intrusive and metamorphic in nature. The results of the calculated radiological parameters conducted shows that most of the parameters are low in relation with the approved World normal while few parameters have values higher than the approved limit. Moreso, radiological parameters estimated from groundwater samples, Grdw sample 7 has the least value while Grdw 15 has a highest value. This Grdw 15 sample poses a serious threat to the inhabitant within the study area and a repeat of geochemical analysis is needed on this sample and other groundwater samples that shares similar hydrogeological characteristics. However, the reports of water borne diseases reported by the medical personnels in some of the clinics around the area is justifiable and it is of a great concern to the government of the country that must be addressed as urgent as possible.

Therefore, most of the groundwater samples investigated are potential probabilistic incidence of disease such as mutation, cancer, etc. Hence, it has become necessary for government through the management of the school to give a regulation to the landlords of the affected samples on the need for a clean and odor free water for their tenants.

This study therefore recommends a radiation remedy on the affected groundwater samples and the result estimated can serve as a reference point for forthcoming studies.

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