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Study of Radiation Pollution of Groundwater in Al-Tuz, Salah Al-Din Governorate, Iraq

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Abstract: This paper presents an evaluation radiation pollution of groundwater and the radioactive contamination from natural radiation sources using sodium iodide detector by measuring gamma lines emitted from radioisotopes. The radioactivity of the radioisotopes radium (Ra^{226}), Actinium (Ac^{228}) and potassium (K^{40}) were identified in the studied samples, which included 52 different groundwater samples in the city of Al-Tuz, Salah Al-Din Governorate, Iraq. The results show that the concentration of Ra^{226} was between the range (w_{22} (3.712)-w_{45} (191.551)) BqL^{-1}, where some of samples radioactivity was higher than the allowed limit (35BqL^{-1}), but the concentration of Ac^{228} was between (w_{25} (1.609)- w_{29} (42.4) BqL^{-1}) and the concentration of K^{40} was between (w_1 (1.092) - w_{18} (123.164)) Bq L^{-1} where all the results were below the allowed limit of (400BqL^{-1}), and the radium equivalent was between (w_{22} (20.613434) -W_{45} (212.02739)) BqL^{-1}, where all the results were below the global limit (370)BqL^{-1}. The rate of absorbed dose AD was between (9.7047138-97.434442) $nGyh^{-1}$ that 20 samples appeared above the allowed limit and the rest of the samples was less than the allowed limit (84Bq L^{-1}). The annual effective dose of Ra^{226} concentration was between (0.065097- 0.001261) mSv/year showed that all the results were less than the global limit of (0.1 mSv / year).

Keywords: Radiation Pollution, Groundwater, Radionuclides

1. Introduction

Radioactive material is found throughout nature. It is in the soil, water, and vegetation. Low levels of uranium, thorium, and their decay products are found everywhere. Some of these materials are ingested with food and water, while others, such as radon, are inhaled. The dose from terrestrial sources also varies in different parts of the world. Locations with higher concentrations of uranium and thorium in their soil have higher dose levels [1]. The major isotopes of concern for terrestrial radiation are uranium U^{238}, thorium Th^{232}, actinium $Ac^{238}$and the decay products of uranium, such as thorium, radium, and radon [2] addition to the cosmic and terrestrial sources, all people also have radioactive potassium-40, and other isotopes inside their bodies from birth. The variation in dose from one person to another is not as great as the variation in dose from cosmic and terrestrial sources [3].

Due to the importance of water in human life and living organisms in all areas, especially in food and drink, the aim of this study is the measurement of the concentration of radium, actinium and potassium in the groundwater samples in AL-Tuz,. We also aims to determine the radium equivalent, absorbed dose and effective dose of radium Ra^{226}.

2. Theoretical Part

2.1. Specific Activity Concentration (A)

Specific efficacy is defined as the radiation effectiveness of the mass unit and the volume of the radioactive material and is measured in Ci per gram or (Bq /kg) or (Bq /m^3) [4].

$$A(Bq/L) = \frac{N}{\varepsilon \cdot I_\gamma \cdot V \cdot t} \quad (1)$$

where:

N: Count net under the top, E: The efficiency of the gamma detector

I: The percentage of potential gamma emission of radionuclides under study

M: Model block in kg unit, T: Counting time in second unit

2.2. Radium Equivalent Activity (Ra_{eq})

Ra_{eq} is defined as a radiological factor used to ensure the uniform distribution of natural radionuclides, namely radium-226, thorium-232, and potassium-40, measured in Bq/l unit and can be calculated by the following law

$$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_{k} \quad (2)$$

where A_{Ra}, A_{Th}, and A_K are the radioactive activity of radium-226, thorium-232, and potassium-40 in Bq /l, respectively. The maximum allowable value of radium equivalent (370Bq/kg) [5].

2.3. Absorbed Dose (D_γ)

The rate of absorbed dose of gamma ray in air (D_γ) at 1m above ground level can be calculated using the specific efficacy of radium-226 and thorium-232 and potassium-40 as in the following equation [6].

$$D_\gamma \text{ (nGy/h)} = 0.461A_{Ra} + 0.623A_{Th} + 0.0417A_K \quad (3)$$

The conversion factors used to calculate the absorption rate of gamma radiation corresponded to (0.462 nGy/h) for radium-238, (0.604nGy/h) for thorium-232 and (0.0417nGy/h) for potassium [7].

2.4. Estimation of the Annual Effective Dose from Ra-226 Concentration in Groundwater

Radium is one of the most important radioisotopes to be identified in water, including drinking water, for its long half-life and radiation effects, especially since its behavior in the human body is like calcium, and more than 70% of this is concentrated in the bones. The effective dose due to the consumption of two liters of water as a daily average containing a certain concentration of radium can be calculated using the following formula [8].

$$\text{Effective Dose (Sv)} = A \text{ (Bq /l)} X A_1 \text{ (l)} X CF \text{ (Sv / Bq)} \quad (4)$$

where as

A: Concentration

A_1: The annual rate of consumption of drinking water per capita is estimated at 720 liters

CF: The conversion factor is equal to ($4.72x10^{-7}$Sv/Bg) for radium in water

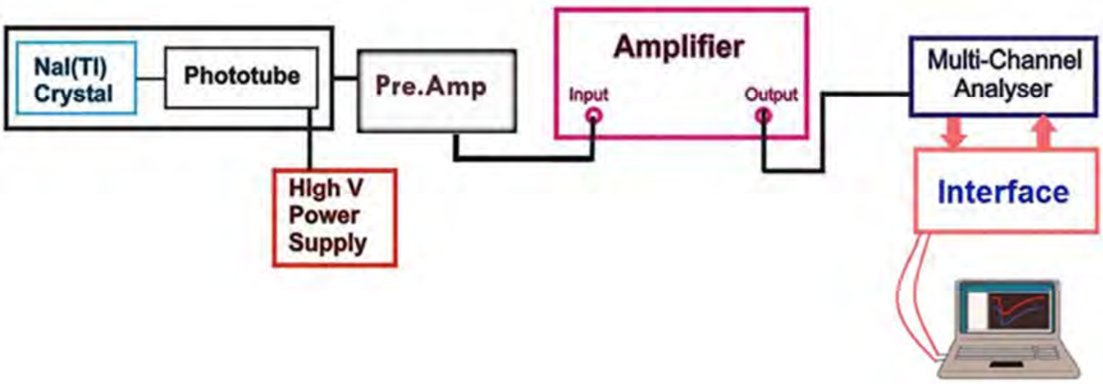

Figure 1. *A scheme for the flash detector system (NaI(Tl)).*

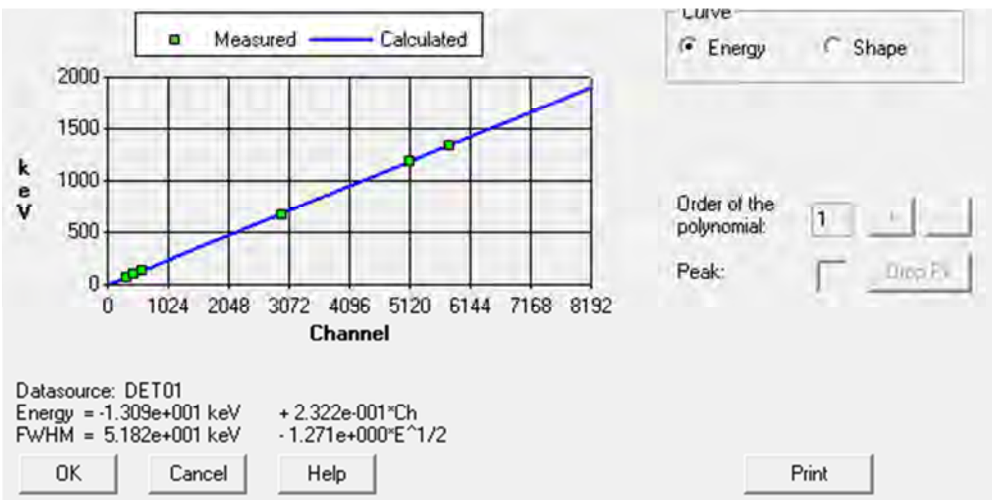

Figure 2. *Energy calibration curve for NaI (Tl) sodium reagent detector.*

3. Materials and Methods

In this study, the technique of spectral analysis of gamma rays is used. The detector and measurement system, is shown in Figure 1, consists of NaI (TI) detector with size of the (3 × 3), the voltage of (691) Volt, the efficiency of 60%, and the energy separation (6.5-8.56%) for value energy (661-1332) MeV. The detector base is surrounded by a shield of lead to protect it from radiation background. This system consists of a primary amplifier, a main amplifier, and a multi-channel analysis. This system is connected to a computer to read its measurements and analyze the results.

3.1. Calibration of the System

For the purpose of calibrating the sodium iodide detector, a multi-energy source (cobalt (Co^{60}), cesium (Cs^{137}), and europium (Eu^{152})) was placed in front of the detector for a period of time (3600 seconds) and Figures 2 and 3 show energy and efficiency calibration curves.

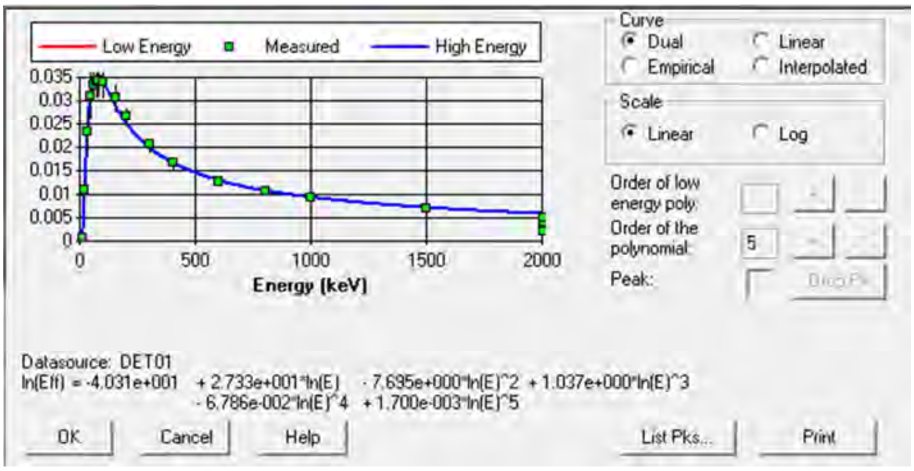

Figure 3. *Efficiency calibration curve of the sympathetic oxidation detector.*

3.2. Sample Collection

A total of 52 samples were collected and presented in Table 1 of ground water for different areas in Al- Tuz Khurmatu, Salah –Al-din Governorate, shown in Figure 4, and each sample size was 5 L in order to increase the sample concentration, we heated the sample by 100°C until the size of sample reaching 1L for each sample, and then we put the samples in Marinelli Baker after it has been fixed around the crystallization of the detector and has reached the measurement time for each sample (3600 seconds). Figure 4 shows the locations of the studied samples on the map.

Table 1. *The locations, depth and date of wells and uses.*

Sq	Well location	Depth of well	History of drilling well	Uses
1	Near the southern control of Tuz	105	2004	The gravel and sand factory
2	Near the village of Yekja	110	2014	Animal Husbandry
3	East of Yenjja village	120	2008	The gravel and sand factory
4	Between the village of Jaragli and the village of Yenkja	120	2006	The gravel and sand factory
5	Between Tuz and the village of Gardagli	155	2015	Animal husbandry and agriculture
6	North of Gardagli village	100	1990	Agriculture
7	South of Gardagli village	72	2009	Agriculture
8	Downtown Gardagli Village Village	70	2009	drink
9	West of Gardagli village	70	2012	Animal husbandry and agriculture
10	North of Bustamli village	100	2008	Agriculture
11	West of Qarnaz village	40	2013	Agriculture
12	South of Karnaz village	100	1970	drink
13	North of the village of Albu Hassan	91	2011	Agriculture
14	Between Amri and Qarnaz villages	87	2011	Animal husbandry and agriculture
15	The middle of an amusing hand	80	2011	Agriculture
16	Near the village of Shukr	145	2002	Agriculture
17	Near the village of Wadi	88	1988	
18	Near my hand	120	2007	Animal Husbandry
19	Al - Tayyar District	85	2009	Agriculture
20	Inside Brougli Village	155	1973	drink
21	North of Braugli village	155	1999	Animal husbandry and agriculture
22	Neighborhood officers - Tuz	65	2009	wash
23	Imam Ahmed neighborhood	90	2012	Cultivation and drinking
24	The Shrine of the Imam Ahmed A. West of Tuz	95	200	wash

Sq	Well location	Depth of well	History of drilling well	Uses
25	Khadasarli Village	110	2009	Block Factory
26	Cox Village	71	2004	drink
27	North of Cox		2012	drink
28	Khadasarli Village	55	2016	Agriculture
29	North Solomon Peck	83	2013	Block Factory
30	Near Solomon Beck	112	2009	Block Factory
31	Central Solomon Beck	105	2013	Block Factory
32	West Solomon Peck	100	2015	Agriculture
33	North Qazaa Tuz	144	2012	Agriculture
34	East Qazaa Tuz	138	2013	Animal husbandry and agriculture
35	West of Tuz	120	2010	drink
36	West of Tuz	125	2010	drink
37	Near Western control of the vigil	110	2009	Agriculture
38	Aksu-Tuz district	110	1999	Agriculture
39	Between Tuz and the village of Braugli	40	2009	Drink and cultivate
40	The mud district - Tuz	80	2010	Agriculture
41	The village of Albu Sabah	150	2006	Animal husbandry and agriculture
42	North of the village of Albu Sabah	155	2014	Agriculture
43	East of the village of Albu Sabah	140	2005	Animal husbandry and agriculture
44	Modern morning morning	130	2011	Agriculture
45	The village of Halwa large	1450	2014	Animal husbandry and agriculture
46	The village of Halawa small	140	2013	Animal husbandry and agriculture
47	West of Tuz	72	2015	Animal husbandry and agriculture
48	West of Tuz	79	2010	Animal husbandry and agriculture
49	Imam Hassan neighborhood - Tuz	130	2003	Agriculture
50	Al-Zabat neighborhood - Tuz	60	2013	Agriculture
51	Near the village of Braugli	90	2000	Animal husbandry and agriculture
52	Near the village of Braugli	95	2013	Animal Husbandry

4. Results and Discussion

In this survey, a total number of 52 ground water samples were collected and analyzed as fallow:

1. Radionuclides activity of Ra ^{226}, Ac^{228} and K^{40} were represent in Table 2 and shown in Figure 5. The results show that the concentration of radium were between Ra^{226} ((w_{22} 3.712-w_{45}191.551) Bq L $^{-1}$ where some samples activities were higher than the allowed limit of (35Bq L^{-1}). The concentration of Ac^{228} was between (w_{25} 1.609-w_{29} 42.4 1.609) Bq L^{-1}. The concentration of K^{40} was between ($w_1$1.092- w_{18}123.164) Bq $L^{-1}$where All results were below the global limit of (400Bq L $^{-1}$).
2. Radium equivalent Table 2, which is calculated using Equation 2 and Figure 6 shows the radium equivalent a function of the groundwater samples. The results between (W_{22}20.613434 _W_{45} 212.02739) Bq L^{-1} and all the results were below the global limit of (370BqL^{-1}) [8]
3. Gamma dose rate is calculated from equation (3). Figure (7) shows the absorbed dose rate as a function of groundwater samples. The results between (W229.7047138- W_{45}97.434442) $nGyh^{-1}$ and 20 samples appeared above the allowed limit and the rest of the samples were less than (55 BqL^{-1}) [9].
4. Effective dose resulted from the radium concentration using Equation (4), Figure (8) shows the results between (0.065097- 0.001261) mSv/year showed that the results were all less than the global limit (0.1) mSv/year [10].

Figure 4. *The locations of the models studied on the map.*

Table 2. *Radionuclides concentrations of, radium equivalent dose-uptake rate, and annual dose of radium.*

Sample ID	Ra-226	Ac-228	K-40	Ra eq (Bg/L)	Absorbed Dose rate (nGyh-1)	Effective Dose mSv/year
W1	112.582	21.806	1.092	143.848664	65.5306488	0.03826
W2	109.152	33.755	20.699	159.015473	72.2053756	0.037094
W3	42.659	14.382	36.131	66.007347	30.1216084	0.014497
W4	143.572	9.725	68.272	162.735694	75.0718278	0.048792
W5	55.659	3.421	6.136	61.023502	28.0441124	0.018915
W6	174.280	12.979	79.819	198.986033	91.7335036	0.059227
W7	83.568	4.373	110.731	98.347677	45.8334904	0.0284
W8	99.200	2.270	70	107.8361	50.04341	0.033712
W9	119.680	25.530	18.27	157.59469	71.834048	0.040672
W10	161.568	14.189	7.327	182.422449	83.6259328	0.054907
W11	46.889	34.154	77.484	101.695488	46.1016086	0.015935
W12	61.8192	31.581	3.022	107.212724	48.298725	0.021009
W13	45.315	7.666	29.903	58.579911	26.9041172	0.0154
W14	97.127	4.206	36.818	105.976566	48.9201502	0.033008
W15	165.726	20.279	21.431	196.375157	89.9207464	0.05632
W16	76.889	6.338	18.487	87.375839	40.1597648	0.02613
W17	165.726	8.130	58.983	181.893591	83.9065722	0.05632
W18	123.881	29.006	123.164	174.843208	80.2788686	0.0421
W19	63.836	4.914	81.5	77.13852	35.863918	0.021694
W20	46.889	8.606	29.449	61.463153	28.1965556	0.015935
W21	163.627	16.671	75.927	193.312909	88.9614578	0.055607
W22	3.712	7.499	80.232	20.613434	9.7047138	0.001261
W23	152.732	26.860	30.59	193.49723	88.409658	0.051904
W24	86.713	4.356	28.468	95.134116	43.8670562	0.029469
W25	54.676	1.609	62.738	61.807696	28.8053962	0.018581
W26	44.710	6.354	30.306	56.129782	25.8245204	0.015194
W27	46.122	13.481	7.83	66.00274	29.985067	0.015674
W28	91.679	11.487	29.903	110.407941	50.6584042	0.031156
W29	77.031	42.400	26.469	139.701113	63.0223076	0.026178
W30	74.610	23.901	17.401	110.128307	50.0059344	0.025355
W31	116.94	14.034	61.135	141.716015	65.183511	0.039741
W32	100.396	10.754	54.541	119.973877	55.2402954	0.034119
W33	48.059	15.848	35.536	73.457912	33.4996934	0.016332
W34	32.311	9.622	5.5411	46.4971247	21.11927854	0.010981
W35	63.352	14.999	43.917	88.182179	40.3678128	0.02153
W36	90.025	5.861	19.966	99.943612	45.9795204	0.030594
W37	125.051	9.004	25.049	139.855493	64.2950316	0.042497
W38	152.571	18.061	44.159	181.798473	83.4154166	0.05185
W39	137.560	15.822	40.482	163.302574	74.9482208	0.046748
W40	145.751	17.392	31.689	173.061613	79.3383516	0.049532
W41	77.475	3.190	40.848	85.181996	39.3944522	0.026329
W42	70.996	6.339	38.759	83.045213	38.2829756	0.024127
W43	61.213	5.492	4.487	100.19879	31.8264708	0.020803
W44	74.166	7.576	63.379	111.946466	41.5342646	0.025205
W45	191.551	12.889	26.56	212.02739	97.434442	0.065097
W46	124.811	6.792	23.172	136.307804	62.7286078	0.042416
W47	56.119	9.321	22.476	71.178682	32.6083484	0.019071
W48	12.145	7.654	57.746	27.536662	12.7579714	0.004127
W49	14.242	27.001	33.43	55.42754	24.771187	0.00484
W50	18.144	1.929	21.431	22.552657	10.4533944	0.006166
W51	98.257	2.925	14.7	103.57165	47.727332	0.033392
W52	83.326	6.239	103.26	100.19879	46.575147	0.028318
W. A				370	55	0.1
MAX	191.551	42.4	123.164	212.02739	97.434442	0.065097
MIN	3.712	1.609		20.613434	9.7047138	0.001261

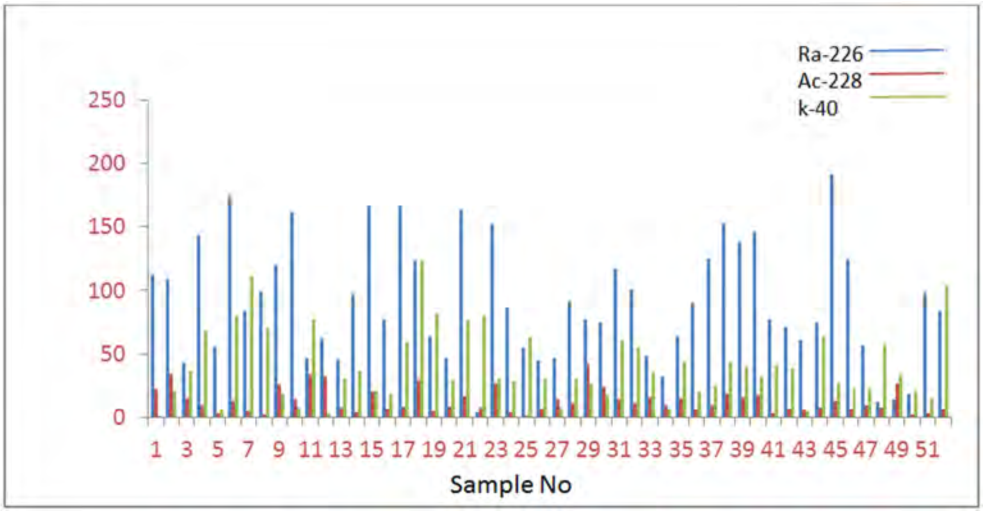

Figure 5. *Radionuclide concentrations for the following epochs (Ra^{226} , Ac^{228} and K^{40}).*

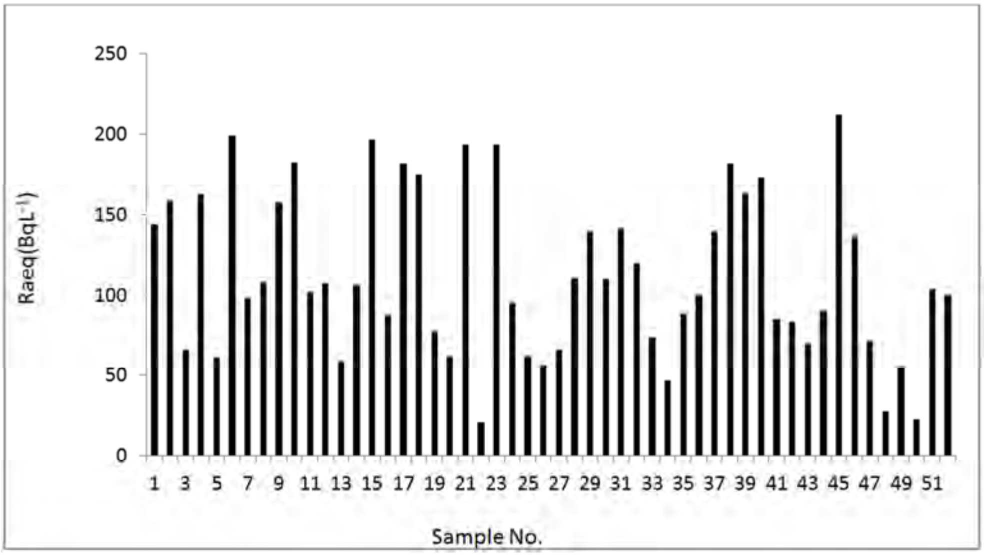

Figure 6. *The relationship between Radium equivalent and water samples.*

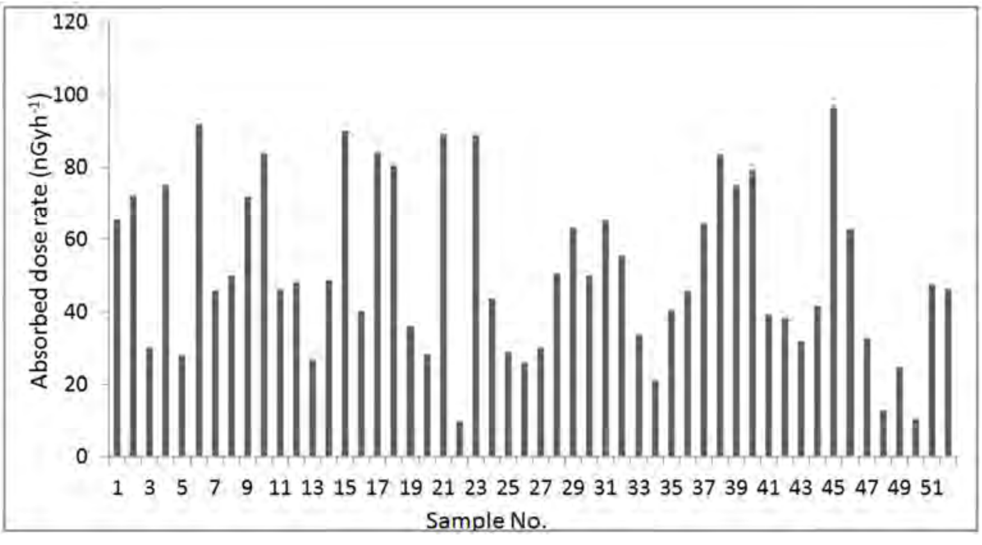

Figure 7. *The relationship between the absorbed dose rate in water samples number.*

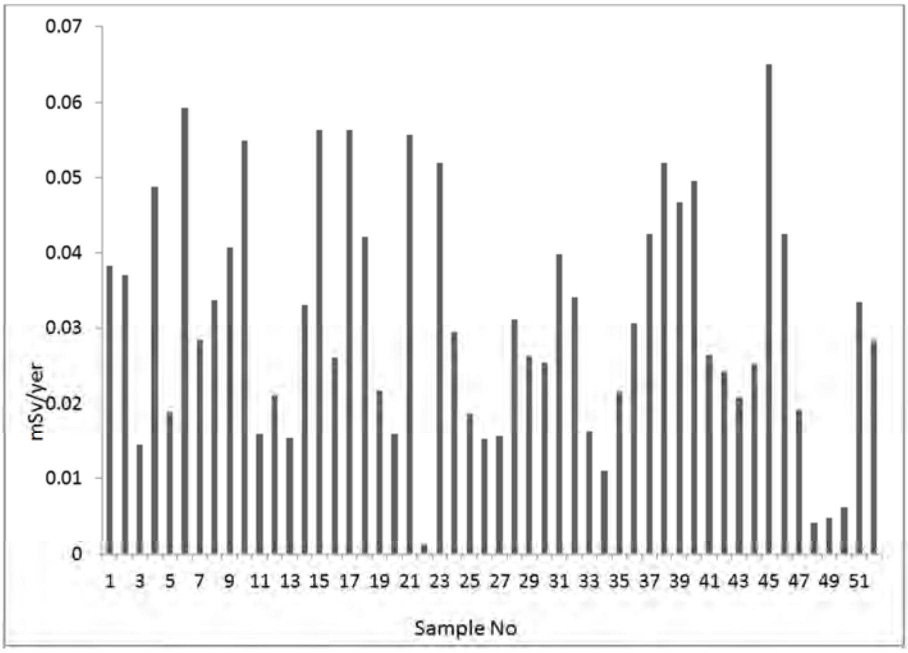

Figure 8. *Determination of the annual effective dose resulting from radium concentration in water.*

5. Conclusions

From this work the fallowing conclusions were found:

Gamma dose rate appeared above the allowed limit in very old samples and the others new samples were less than (55 BqL^{-1})

Effective dose resulted from the radium concentration showed that the results were all less than the global limit (0.1) mSv/year

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