ENVIRONMENTAL AND RADIOLOGICAL POLLUTION IN CREEK SEDIMENT AND WATER FROM DUHOK, IRAQ

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The activity concentrations of terrestrial (^{226}Ra, ^{232}Th and ^{40}K) and anthropogenic gamma emitting radionuclides (^{137}Cs) have been measured in 28 creek water and sediment samples randomly selected in different locations of Duhok governorate. The governorate is located in the northwest Kurdistan region of Iraq. Determination of the human health risk from the three exposure pathways (External radiation, Inhalation and Ingestion) was carried out. In addition, the chemical analysis was performed for the 13 surface water samples for reliability of physical results. Gamma spectroscopy system with a shielded well type NaI(Tl) detector used for 40000 sec per sample. The data analysis included elemental concentrations, air absorbed dose rate, annual effective dose rate and external hazard index (radium equivalent activity). The average of 49.81±1.69 nGyh^{-1} in sediment and 21.19±1.32 nGyh^{-1} in water samples were below the world average value of 57nGyh^{-1}. The corresponding annual effective dose rates outdoor estimated for sediment and surface water were 61.13±2.1µSvy^{-1} and 26.01±1.62 µSvy^{-1} respectively. The calculated external hazard indexes (H$_{ex}$) 0.29+0.01 for sediment and 0.112+0.007 surface water samples. These values showed that all samples were well below the hazard limit of unity. The RESRAD-6.5 computer code was used to analyze the dose per unit release of a specified radionuclide and the health risk from the three exposure pathways. RESRAD code showed over estimation of the results of annual effective dose rates, even though the results were within the background level. The average value of activity concentrations of the radionuclides of sediment samples by the code was 0.108 mSvy^{-1} compared to our calculations. The probability of human cancer risk lifetime of a hypothetical contamination consisted of the highest value of the activity concentrations of terrestrial radionuclides and ^{137}Cs is 17 people from 10000. The chemical analysis of the surface water samples showed compatibility with radiological results in terms of the solubility of isotopes. The radiological impact due to exposure pathways, as analyzed by RESRAD software and from other results indicated that the environment of the governorate was clean and suitable for living.

Keywords: Environmental radioactive sources, Surface water samples, Annual effective dose rate, RESRAD computer code

1. Introduction

Today, the issue of environmental pollution has become an important topic to be discussed at all international levels, and to organize international conferences to find solutions for the issue. Natural radionuclides are present in varying amounts in air, water, plants, animals, soil and rocks. Naturally occurring radionuclides and particularly their decay products are transported in ground and surface water. Uranium for instance is found in ground and surface waters due to its natural occurrence in geological formations. The average uranium concentrations in surface, ground, and domestic water are 1, 3 and 2 pCi/L, respectively. The uranium intake from water is equal to the total from other dietary components [1]. As a result, these radionuclides may enter the food chain through irrigation waters, and the water supply through groundwater wells and surface water streams and rivers [2]. The land surface is contaminated by the nuclear fallout caused by nuclear weapons tests. Also nuclear accidents such as that of Chernobyl nuclear reactor in 1986 and recently Fukushima nuclear plant disaster released a high radioactivity specifically from ^{131}I, ^{137}Cs and ^{134}Cs to the atmosphere. The radioactive decay of all these radionuclides makes them suitable for dating sediments. There are appropriate models of the

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processes by which they enter the ecosystem and are incorporated in the soil/sediment [3, 4].

The assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population. These doses vary depending upon the concentrations of the natural radionuclides ^{235}U, ^{238}U, ^{232}Th, their daughter products and ^{40}K present in the soil and rocks, which in turn depend upon the local geology of each region in the world [5]. These radionuclides are ubiquitously present in low concentrations in soil and water because of weathering and erosion of rock. Another major exposure pathway to natural radiation results from the decay of ^{226}Ra in the ^{238}U series. The decay results in the formation of gaseous ^{222}Rn, which can enter the atmosphere through emanation from soil and building materials. The principal sources of internal exposure and major component of total background radiation exposure are the rapidly decaying radionuclides formed as a result of decay of ^{222}Rn. Exposure occurs when these radionuclides, namely ^{222}Rn, ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po, are inhaled and retained in the lungs [6]. A large fraction of natural radiation exposure is due to ingestion of food containing natural radionuclides such as ^{40}K, ^{226}Ra, ^{210}Po and ^{210}Pb. For example, ^{40}K is an important radionuclide from the health physics point of view. It is the largest contributor of the dose received by human due to its wide spread distribution in environment and living organisms ($t_{1/2}$=1.3 billion years). The concentration of potassium as an essential element of the body is under homeostatic controls and one can find about 2 g of this element in one kg of the body mass used to sustain biological process. The average natural abundance of ^{40}K is about 0.012%, but the internal dose depend on the rate of the radionuclide elimination from the body (biological half-life), for ^{40}K is 30 days [7].

For the first time, a verification and analysis of radioactivity pollution is conducted for the Creeks and their settled mud in Duhok governorate. Also chemical analysis of the Creek water samples is performed for the measurement of pH, alkalinity, and dissolved solids - etc. The main aim of this research is to analyze the exposure pathways that affect the human health due to the exposure to nuclear radiation and monitoring the environmental radioactive isotopes in the Creek water and the settled mud of Duhok governorate. The research

assesses the level of radiation and the environmental radioactivity concentration and doses especially of long lived terrestrial isotopes such as ^{226}Ra, ^{232}Th, ^{40}K, as well as ^{137}Cs deposited on the ground. In addition the research aims to establish a baseline radiation level of the region.

2. Study Area

Duhok governorate lies in the far north-west of Iraq and forms the western governorate in Iraqi Kurdistan Region (Fig. 1). It confines with Turkey from the north, Syria from the west, Erbil governorate from the east, and Nineveh governorate from the south. It is a part of the mountain and semi-mountain that orientated from west to east, in physiographic diversity from the middle and south of Iraq. The governorate is divided managerially into the following four districts: Duhok-district with area (1092) km^2, Sumel-district with area (1327.7) km^2, Zakho-district with area (1521.51) km^2, and Amadi-district with area (2582.8) km^2 [8].

The climate of the Region is of semi-arid type, designated as continental and subtropical. The elevation is quite different ranging from lower than 300 to more than 1300 meters above the sea level. During the summer, the average temperature does not normally exceeds 38 ^{o}C at its peak and drop below 0 ^{o}C in winter [8].

The geological formations consisting of limestone, red beds of silt, hard clay stone with some beds of siltstone and conglomerate and formation of well bedded chalky, partly dolomite limestone with thin beds of yellowish-green marl. Soil Quality; the area is generally characterized by thick sedimentary cover and well marked folds of asymmetrical anticlines and broad synclines. The area is entirely located within the low folded zone. This soil throughout investigation is classified as soil of a very low permeability, moisture of sediment of depth from (5 to 10cm) of 6-7% and the average mass density of 1700 Kg/m^3 [9].

All the natural water resources comes from rains, snows and grounds waters and superficial water to present the actual water sources of Duhok governorate. Superficial water is considered the main source to the governorate. Most of the irrigated lands at the bottom of the valleys are
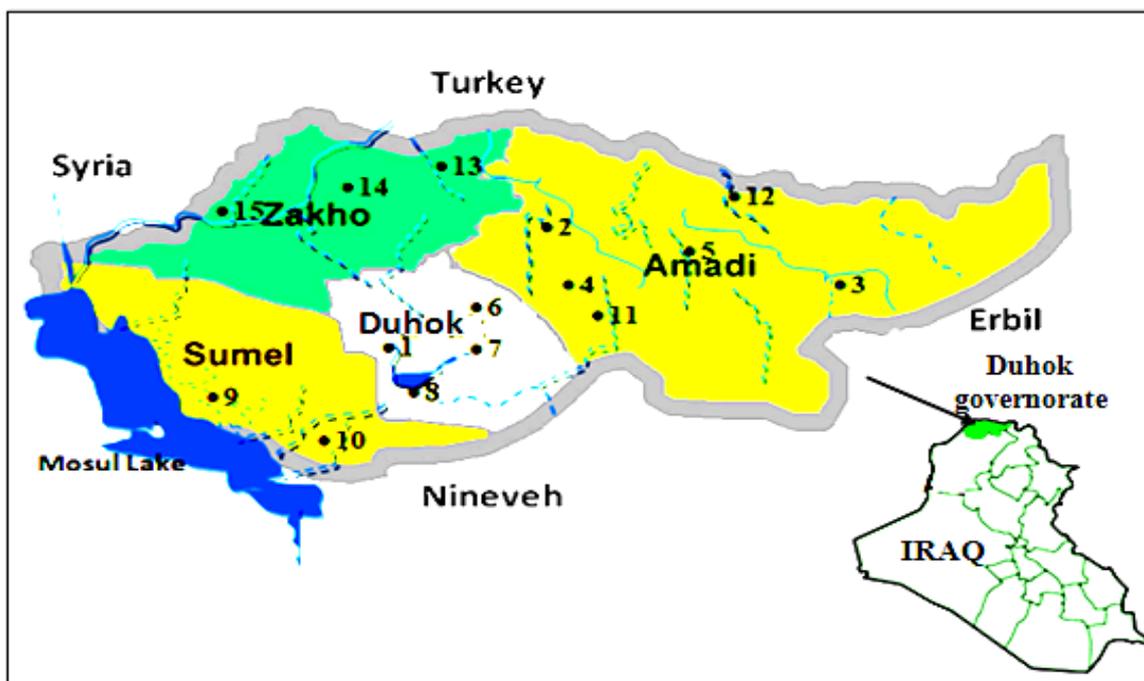
Figure 1. Locations of the sediment and water samples in Duhok Governorate.

irrigated by rivers, streams and springs. However, small diesel pumps are used to lift water from the existing streams to strips of lands along these streams [8].

3. Field and Laboratory Works

The dose rates in the 15 desired locations were measured first by the gamma scout radiation meter (dosimetry) for periods of one hour for surface water and one hour for sediment approximately 2m far from the crack at 1m above the surface water and sediment. The data transferred to a personal computer via connection with USB port of PC [10].

A total of 15 sediment and 13 surface water samples (where two locations do not have water) has been collected from different sites throughout Duhok Governorate, for each site, an area for sediment of about 30cm×30cm was marked and carefully cleared of debris, and a sediment sample of depth (5-10) cm collected, depending on a standard methodology [11, 12].

The collected sediment samples were dried at room temperature in open air for two days then dried in an oven of 110°C for one hour then crushed and passed through a fine mesh sieve of 2 mm. The homogenized samples were packed in

a standard 1000 ml marked plasto Marinelli beaker hermetically sealed, these samples stored for more than four weeks prior counting to ensure equilibrium between decay products [13]. The surface water samples are collected from each location in plastic bottles to be ready for physical and chemical analysis.

The counting is carried out by a γ-ray spectrometry system consisted of a 3"×3" NaI(TI) well type detector for a period of 40000 sec. The detector is housed upside down in a cylindrical lead shield of thickness about 6cm which is suitable for limiting the gamma background. A multi-channel buffer (MCB) used is a PC-based plug in PCI card consisting of 8k analog digital convertor (ADC) with sophisticated WINDOWS based control and analysis software MCDWIN to analyze the γ-ray spectrum [14].

The naturally occurring radionuclide considered in the present analysis of the measured gamma ray spectra are: ^{235}U (with a main gamma energy at 185.7 KeV with gamma fraction 57.2%), ^{226}Ra (with energy186.2 KeV and gamma yield of 3.55%), ^{212}Pb (238.6 KeV, 43.6%), ^{214}Pb (351.9 KeV, 35.6%), ^{214}Bi (609.3 KeV, 45.49%), ^{137}Cs (661.6 KeV, 85%), ^{40}K (1461 KeV, 11%), ^{214}Bi(1764.5 KeV,15.28%) and ^{208}Ti (2614.8 KeV, 35.85%).

Under the assumption that secular equilibrium has been reached between ^{232}Th, ^{226}Ra and ^{235}U and their decay products, a direct measurement of ^{40}K and ^{137}Cs concentration is achieved.

Based on the measured γ-ray counts (N_{Ei}) at full width at half maximum (FWAM) photo-peaks of specified radionuclides in the ^{232}Th and ^{226}Ra decay series and in a single ^{40}K and ^{137}Cs, their specific activity or activity concentrations (activity per unit mass) in samples can be calculated from the following equation:

$$C_e = \frac{1}{M_s \times n} \sum_{i=1}^{n} A_{Ei} (BqKg^{-1}),$$

where $A_{Ei} = \frac{N_{Ei}}{\varepsilon_E \times t \times f_\gamma} (Bq)$ (1)

and ε_E is the detection efficiency at energy E_i, t = 40000 s, f_γ is gamma fraction, M_s is the mass in kg of the measured soil samples, and n is number of photo-peaks, such that of ^{40}K and ^{137}Cs (n=1) and that of selected daughter radionuclides in the decay series of ^{232}Th and ^{238}U (n=2).

The total elemental concentrations of thorium, uranium and potassium, respectively, according to the following expression [15].

$$F_e = \frac{M_e . C_e . P}{\lambda_e . N_A . f_{A,e}}$$ (2)

where F_e is the fraction of element e in the sample (Bqkg^{-1}), M_e is the atomic mass (kg.mol^{-1}), λ_e is the decay constant (s^{-1}) of the parent radioisotope, N_A is Avogadro's number (6.023×10^{26} atoms.mol^{-1}), $f_{A,e}$ is the fractional atomic abundance of ^{232}Th, ^{238}U or ^{40}K in nature, P is a constant (with a value of 100 or 1,000,000) that converts the ratio of the element's mass to soil mass into a percentage or ppm respectively.

The gamma dose rate (D) in nGy h^{-1} in the outdoor air at 1 m above the ground is calculated by following equation [16].

D=0.462 C_{Ra}+0.604 C_{Th}+0.042 C_K +0.1243 C_{Cs} (3)

The annual effective doses can be calculated as:

Annual effective dose (Sv) =D×24×365×0.7×0.2 (4)

The external hazard index, H_{ex}, is defined as:

$$H_{ex} = \frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810}$$ (5)

The value of this index must be less than unity for radiation hazard insignificant. The maximum value of H_{ex} equal to unity corresponds to the upper limit of radium equivalent activity (370 Bqkg^{-1}) [17].

The radiological impact due to the three exposure pathways (External radiation, Inhalation and Ingestion) has been analyzed using The RESidual RADioactivity (RESRAD version 6.5) model and computer code [18]. Exposure to external radiation occurs primarily as a result of radiation emanating from radionuclides in the contaminated zone. In our case, we consider both the average dose rate of the region and assumed the highest concentration of each radionuclide of the sediment samples as a hypothetical contaminated zone to analyze the RESRAD output [18].

4.   Results and Discussion

4.1.   Radioactivity

Using Gamma scout radiation meter, the results of dose rate (μSvh^{-1}) measurements are ranged between (0.11-0.176) μSvh^{-1} for water and (0.132-0.281) μSvh^{-1} for sediment. While the average values are 0.147 μSvh^{-1} and 0.188 μSvh^{-1} for Water and Sediment respectively.

The major gamma-ray emitted by ^{235}U, at 185.72 KeV is almost at the same energy as that emitted by ^{226}Ra at 185.99 KeV. Even though the resolution of this mutual interference is difficult, the analysis will be performed assuming that the entire 186 KeV peak is due to ^{226}Ra. We can then use the following correction factors to correct the ^{226}Ra value and derive an additional result for ^{235}U [19]:

Corrected ^{226}Ra = 0.5709×Apparent ^{226}Ra

Estimated ^{235}U = 0.02662×Apparent ^{226}Ra

The activity concentrations (Bqkg^{-1}) of ^{226}Ra, ^{235}U, ^{232}Th, ^{40}K and ^{137}Cs for 15 sediment and 12 water samples collected from different locations in Duhok Governorate are calculated by Eq. 1. The results for sediment sample and for water samples are shown in Table 1 and Table 2 respectively.

Table 1. Nuclide Activity concentration (Bqkg^{-1}) of sediment samples.

Sample site	Activity concentration (BqKg^{-1})				
	^{226}Ra	^{235}U calc.	^{232}Th	^{40}K	^{137}Cs
DS1	11.24±1.43	0.03±0.0	30.9±0.8	259.7±2.2	0.2±0.1
DS2	42.66±2.87	ND	29.5±1.2	775.7±5.8	ND
DS3	41.8±2.1	0.01±0.0	20.9±2.1	288.9±3.8	ND
DS4	14.65±1.3	0.01±0.0	34.6±0.9	669.2±5.5	ND
DS5	19.13±1.12	ND	45.4±1	830.7±5.5	ND
DS6	37.3±3.4	0.02±0.0	85.9±1.9	670.7±5.2	ND
DS7	15.99±0.8	0.05±0.0	38.9±4.2	158.9±4.5	1.5±0.3
DS8	12.33±1.3	0.02±0.0	31.8±0.8	122.9±1.5	0.1±0.04
DS9	19.3±1.95	0.03±0.0	41±0.9	471±3.4	ND
DS10	10.8±0.97	0.02±0.0	15±0.7	169.6±1.8	0.7±0.2
DS11	12.86±1.65	0.02±0.0	23.9±1	467.6±3.7	ND
DS12	31.6±1.2	0.03±0.0	58.8±1.1	575.8±3.1	ND
DS13	23.1±1	0.06±0.0	17.4±0.8	193.1±1.9	2.5±0.2
DS14	16.7±1.35	0.02±0.0	36.8±1.9	400.3±2.7	ND
DS15	15.65±0.9	0.014±0.0	19.2±0.8	518.9±6.1	ND
Average	21.67±1.56	0.025±0.0	35.4±1.3	438.2±3.8	1.0±0.1
Range	10.73-44.12	0.01-0.06	15.0-85.9	122.8-830.7	0.1-2.5

Table 2. Nuclide activity concentration (BqL^{-1}) of surface water samples.

Sample site	Activity concentration (BqL^{-1})				
	^{226}Ra	^{235}U calc.	^{232}Th	^{40}K	^{137}Cs
DW 1	4.05±2.35	0.0199±0.01	17.9±0.5	123.5±1.4	ND
DW 2	2.494±0.335	ND	6.5±0.5	43.7±1.3	0.1±0.02
DW 3	2.84±0.35	0.013±0.0	9.1±0.5	69.8±1.1	ND
DW 4	3.4±0.29	0.008±0.0	20.9±1	74.3±1.3	ND
DW 5	4.96±0.45	0.014±0.0	21±0.8	105.3±1.3	ND
DW 6	7.85±0.84	0.013±0.0	79.6±2.1	132.3±1.5	ND
DW 7	6.25±1.0	0.007±0.0	26±1.3	124.5±1.5	ND
DW 8	8.28±0.617	ND	18.7±0.7	110.1±1.5	ND
DW 9	No sample				
DW10	4.5±0.34	0.0067±0.0	30.2±9.5	116.9±1.4	0.1±0.01
DW11	5.1±0.918	ND	12.3±0.8	49.1±1	ND
DW12	5.1±0.6	0.0085±0.0	25.1±1.5	140.3±3.9	0.2±0.04
DW13	3.75±0.22	ND	22.3±0.7	114.5±2.3	ND
DW14	3.03±0.21	0.007±0.0	26.8±0.7	126.6±1.9	0.1±0
DW15	No sample				
Average	4.74±0.66	0.011±0.001	24.3±1.6	102.4±1.6	0.1±0.02
Range	2.49-8.28	0.007-0.02	6.5-79.6	43.7-140.3	0.1-0.2

Table 3. The average dose rate and effective dose compared to the world data.

Country	Dose rate (nGyh^{-1})	Effective dose rates (mSvy^{-1})	Reference
Duhok governorate, Kurdistan, Iraq	49.81	0.0611	Present work
Duhok city, Kurdistan, Iraq	44.05	0.054	[20]
World average value	57	0.5	[17]
Pakistan (Gilgit city)	34.6	0.041	[22]
Nigeria	45.21	0.39	[23]
India	86.54	0.11	[24]
Nigeria	56.06	0.069	[25]
Turkey	-	0.055	[26]
Egypt	43.58	0.05	[6]
Cyprus	14.7	0.018	[15]

The elemental concentration of sediment samples for ^{226}Ra varies from a minimum value 0.88±0.08 ppm in S10 to a maximum of 3.46±0.23 ppm in S2 while for ^{232}Th from 3.71±0.46 ppm S10 to 21.21±0.46 ppm S6. The elemental concentration of ^{40}K varies from 0.4±0.005% S8 to 2.7%±0.018% S5. For surface water samples the elemental concentration for ^{226}Ra varies from a minimum value 0.2±0.03ppm W2 to a maximum of 0.67±0.05 ppm W8, while for ^{232}Th from 1.6±0.12 ppm W2 to 19.65±0.52 ppm W6 and that of ^{40}K from 0.16±0.003% W11 to 0.46%±0.013% W12.

The gamma dose rate (D) in nGyh^{-1} in the outdoor in air from all terrestrial radioisotopes and precipitated ^{137}Cs is calculated using Eq. 3. The calculated values ranged from (17.97±0.8-97.29±2.92) nGyh^{-1}and (6.92±0.51- 57.25±1.71) nGyh^{-1} for sediment and water samples respectively with an average of (49.81±1.69) nGyh^{-1} and (21.19±1.32) nGyh^{-1}.

The annual effective doses as calculated by Eq. 4 for average values of dose rate of sediment and surface water are (61.13±2.1) µSvy^{-1} and (26.01±1.62) µSvy^{-1} respectively.

The average external hazard index, H_{ex} which is calculated using Eq. 5 for sediment and surface water samples are (0.29±0.01) and (0.13±0.007) respectively. For comparison with the worldwide areas, Table 3 shows our average values of the dose rate and annual effective dose with many published investigations, which shows our extracted values nicely fit to these results.

4.2. Health Risk

It has been proven that RESRAD is the most effective tool for evaluating radiological contaminated sites [20]. The RESRAD code incorporates default parameter distributions (based on national average data) for selected parameters. The output dose rates by all pathways of summed (^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs) radionuclides extended to 1000 years are given as tables and graphs.

A hypothetical contaminated zone was assumed by considering the highest concentration of each radionuclide in the sediment samples. The summery of RESRAD non zero total dose contributions for Individual Radionuclides (i) and Pathways (p), Water dependent Pathways (Inhalation excludes radon) and Fraction of total annual dose equivalent at t = 0 is given in Table 4. The RESRAD external TDOSE in the first column (ground) of Table 4 is 0.209 mSvy^{-1} with a fraction 45% while our calculations using Eqs. 3 and 4 is 0.131 mSvy^{-1}. This comparison supports our results and in the mean time what has been reported in [18] "The calculated doses corresponding to guideline values of the radionuclide concentrations are expected to be reasonably conservative estimates (overestimates) of the actual doses." To enhance the above conclusion we run the code for the average values of activity concentrations of the radionuclides to get 0.108 mSvy^{-1} compared to our calculations 0.061 mSvy^{-1} which shows the same comparison.

Table 4. Total dose contributions (TDOSE) for individual radionuclides (i) and pathways (p) at t=0 s by RESRAD.

Radionuclide	Ground		Inhalation		Radon		Meat	
	mSv/yr	fract.	mSv/yr	fract.	mSv/yr	fract.	mSv/yr	fract.
Cs-137	1.280E-03	0.0027	1.364E-09	0.0000	1.162E-04	0.0002	1.016E-04	0.0002
K-40	1.300E-01	0.2772	1.756E-07	0.0000	1.075E-01	0.2292	5.443E-02	0.1160
Ra-226	7.268E-02	0.1549	6.595E-06	0.0000	5.426E-02	0.1157	1.604E-03	0.0034
Th-232	5.410E-03	0.0115	2.440E-03	0.0052	1.190E-02	0.0254	2.583E-04	0.0006
Total	2.094E-01	0.4463	2.447E-03	0.0052	1.738E-01	0.3704	5.639E-02	0.1202

Radionuclide	Milk		Soil		All Pathways*	
	mSv/yr	fract.	mSv/yr	fract.	mSv/yr	fract.
Cs-137	3.319E-05	0.0001	9.142E-07	0.0000	1.532E-03	0.0033
K-40	2.260E-02	0.0482	1.127E-04	0.0002	3.147E-01	0.6708
Ra-226	1.915E-03	0.0041	4.516E-04	0.0010	1.309E-01	0.2791
Th-232	2.062E-04	0.0004	1.791E-03	0.0038	2.201E-02	0.0469
Total	2.475E-02	0.0528	2.357E-03	0.0050	4.691E-01	1.0000

* Sum of all water independent and dependent pathways

The probability of excess cancer risks can be graphically displayed for all nuclides extended to 1000 years as shown in Fig. 2 cut to 100 years for external and all pathways. Comparing to other pathways (inhalation, ingestion and drinking water) we found that the major risk comes from external dose. The probability of cancer risk life time from total doses due to radionuclides for a hypothetical contaminated zoon is 17 people from 10000. While the cancer risk for the average values of the sediment samples is 9 people from 10000.
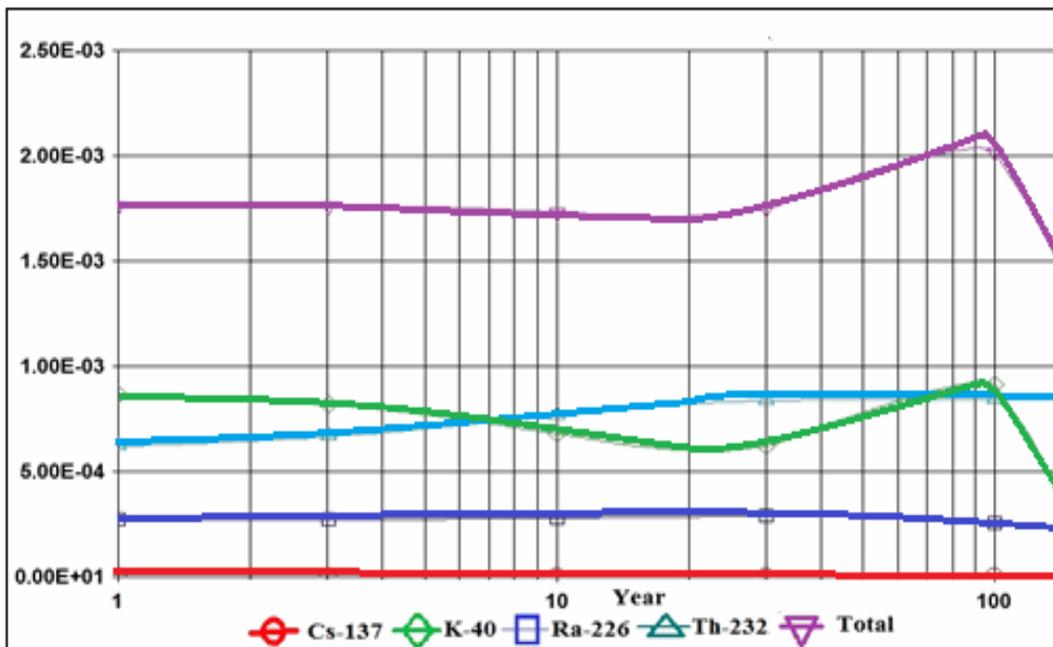
4.3. Chemical Analysis

The main properties of water samples shown in Table 5 are essential to be known in such studies because in most of those locations the superficial water used as drinking water and may cause risk to human. Also the chemical level of some elements in water is suitable to compare with the radiological concentration of equivalent elements, like potassium and radium which are important to our analysis. For instance, the elemental concentrations of potassium element showed a higher concentration of ^{40}K than natural abundance.

The chemical analysis results showed compatibility with radiological results in terms of the solubility of isotopes. Even though the chemical analysis showed an acceptable values of pH and unacceptable alkalinity values in some water samples and hardness in few others that are higher than the maximum permissible level.
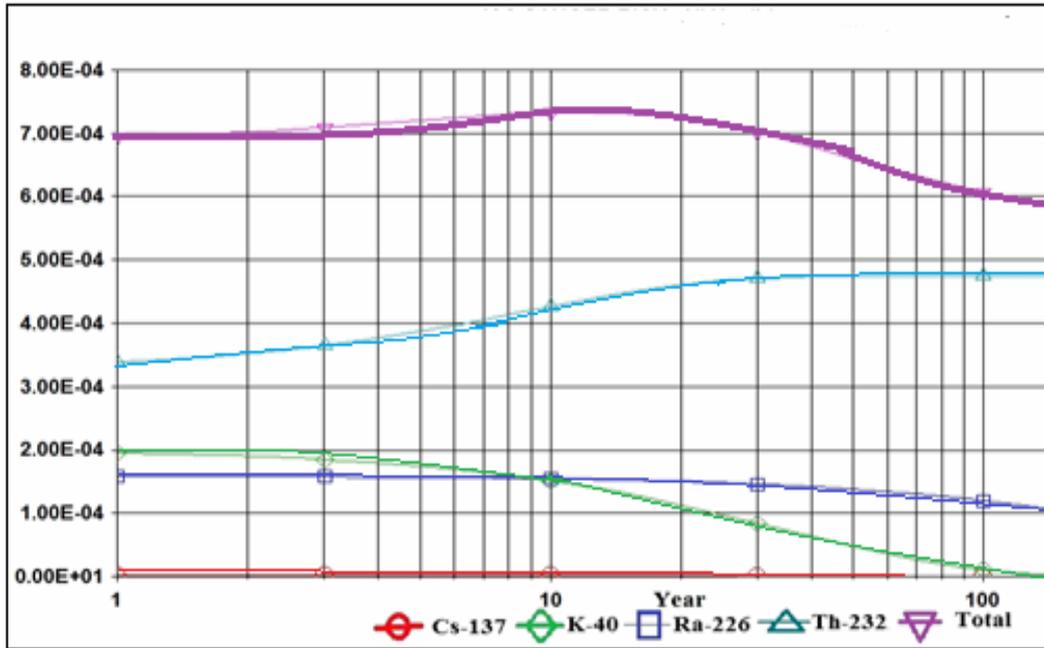
(a)

(b)

Figure 2.   Cancer Risk of all nuclide summed of (a) External, (b) all pathway summed of all radionuclides.

Table 5.   Chemical analysis of water samples.

Sample Code	Turbidity (NTU)	pH	Total dissolved solids	Total Alkalinity	Total Hardness	K (%)
DW 01	0.4	7.72	707.2	78	504	5
DW 02	0.8	8.29	316.1	206	356	3
DW03	0.3	7.73	435.2	178	428	1
DW04	6.7	7.93	491.5	268	440	4
DW05	4.5	7.32	430	258	360	6
DW06	0.4	7.74	412.1	272	376	1
DW07	0.3	8.21	638	182	508	7
DW08	3	8.14	635.5	184	480	7
DW09	–	–	–	–	–	–
DW10	1.0	8.18	697.6	326	500	7
DW11	1.4	8.04	446.7	306	448	5
DW12	1	7.68	383.3	290	416	1
DW13	0.7	7.75	255.3	202	268	1
DW14	1.9	7.8	245.1	186	244	1
DW15	–	–	–	–	–	–
Max. Permissible level	5	6.5-8.5	1000	125-200	100-500	2-3

5.   Conclusion

From the obtained results by γ-spectrometry in all the measured surface water and sediment samples, one can observe that the distribution is not uniform, but agrees well in terms of distribution with the field measurements. Our results are compared fairly well with those of world sites and the UNSCEAR 2000 Report. It is apparent from the results of activity concentrations, and elemental concentrations for water and sediment samples that the difference in the levels of radiation activity is due to the differences in the geological and geographical nature of these regions. The calculated external hazard index for sediment and surface water samples are 0.28+0.01Bq/Kg and 0.112+0.007 Bq/L. these values show that all samples are well below the hazard limit of unity.

The RESRAD Cancer risk measurement appears that the External risk and other pathways risk are within the natural and decrease with passing time. This is obvious since the activity concentrations in our samples are lower than the world average value. RESRAD code shows over estimation of the results of annual effective dose rates and the probability of cancer risk lifetime, even though the results are within a background level.

Comparing the physical and chemical results obtained, it can be concluded that the level of ^{40}K is reasonable but may be over estimated by gamma spectroscopy in surface water. Some elements are more soluble than their parents or daughters under different pH conditions, chemical properties of radioelement, mineral composition and organic matter content. The result is a liquid phase enriched in radionuclides of one natural series and depleted in other. This may explain the low activity ratios of ^{214}Pb/^{214}Bi daughters of ^{238}U and ^{212}Pb/^{208}Ti daughters of ^{232}Th in all water samples.

In addition it is clear that ^{232}Th is more soluble than ^{238}U. The pH value is an important parameter controlling the kinetics of elements in soil and consequently the kinetics of radionuclides. The mobility of radionuclides in soil or sediment due to water stream and rain may be the cause of the lower activity values of radionuclides in water samples than that in sediment sample.

Data used in the present study can also be used as a baseline data for any future study. Moreover, this may provide a data base for any putative radiation measures taken by the government of Kurdistan whenever necessary.

References

[1] A. M. Fan, Public Health Goal for Uranium in Drinking Water, Office of Environmental Health Hazard Assessment California Environmental Protection Agency, August (2001).

[2] P. Vesterbacka, ^{238}U–Series Radionuclides in Finnish groundwater-based drinking Water and Effective Doses, Radiation and Nuclear Safety Authority, STUK, University of Helsinki, Finland (2005).

[3] A. A. Bin- Jaza and A. O. Bazohair, J. Abhath Al-Yarmouk: Basic Sci. & Eng. (2007) 27.

[4] S. Geras'kin, et al., Effects of radioactive contamination on plant populations and radiological protection of the environment, EDP Sciences, Russia (2009).

[5] National Research Council, Radiation Source Use and Replacement Nuclear and Radiation Studies Board Division on Earth and Life Studies, National Academy of Sciences, USA (2008).

[6] A. Nada, et al., J. Appl. Radiat. Isotopes **67** (2009) 643.

[7] K. Arshak, and O. Korostynska, Advanced Materials and Techniques for Radiation Dosimetry, Artech House, Inc. (2006).

[8] Dilshad G. a. Ganjo nad Ela team, Environmental Impact Assessment, (EIA)report, Deralok Hydropower project, Duhok/KRG-Iraq, Map.Com company (2008).

[9] I. A. Abduljabbar, A study of Some Engineering Properties of Undisturbed and Eemolded Desiccated Soils in Duhok governorate, M.Sc. Thesis, College Engineering , Duhok University (2003).

[10] Gamma-Scout radiation detection, product of gamma-scout Ltd. http://www.gamma-scout.com.

[11] M. Pöschl and M. L. Nollet , Radionuclide Concentrations in Food and the Environment, Taylor & Francis Group, LLC, USA (2007).

[12] IAEA, Collection and preparation of bottom sediment samples for analysis of radionuclides and trace elements, International Atomic Energy Agency, Vienna, (2003).

[13] V. Ramasamy, et al., Evaluation of Natural Radionuclide Content in River Sediments and Excess Lifetime Cancer Risk Due to Gamma Radioactivity, Department of Physics, Annamalai University, Annamalainagar, Tam-ilnadu, India, Maxwell Scientific Organization (2009).

[14] D. Fischer, History of the International Atomic Energy Agency: the first forty years, Vienna, IAEA, (1997).

[15] M. Tzortzis and H. Tsertos, Gamma-ray Measurements of Naturally Occurring Radioactive Samples from Cyprus Characteristic Geological Rocks, Department of Physics, University of Cyprus, Nicosia, (2002).

[16] UNSCEAR, Sources, effects and risks of ionization radiation, United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly, with Annexes, New York (2000).

[17] D. Malain, Measurements of NORM in Environmental Samples, Department of Physics, School of Electronics & Physical Sciences, University of Surrey (2007).

[18] C. Yu, et al., Environmental Assessment Division, User's Manual for RESRAD Version 6, Operated by The University of Chicago, United States Department of Energy, July (2001).

[19] G. R. Gilmore, Practical Gamma-ray Spectrometry, 2nd Edition, Nuclear Training Services Ltd. Warrington, UK (2008).

[20] E. R. Faillace, J.-J. Cheng, C. Yu, RESRAD Benchmarking Against Six Radiation

Exposure Pathway Models, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439, October (1994).

[21] K.M.S. Abdullah and R.A. Ramadhan, The Nucleus **48**, No. 4 (2011) 295.

[22] A. Manzoor, et.al. Health Physics **98**, Supplement 2 (2010) S69.

[23] G. O. AVWIRI, J. Appl. Sci. Environ. Mgt. **9** No. 3 (2005) 27.

[24] S. Singh, A. Rani and R. K. Mahajan, J. Radiat. Meas. **39** (2005) 431.

[25] I.C. Okeyode and A.M. Oluseye, J. Phys. International **6**, No.1 (2010) 1.

[26] O. Kilic, M. Belivermis, S. Topcuoglu, Y. Cotuk, M. Coskun., A. Cayir and R. Kucer, J. Radiat. Protect. Dosim. **128**, No. 3 (2008) 324.