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Uranium Concentration and its Associated Health Hazards in Drinking Water of Nineveh Province (Iraq)

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Abstract: Measurements of uranium concentration in water samples for a total of 11 selected locations from Nineveh province were chosen for analysis of uranium concentration using fission track registration technique. A known volume of the water(two drops) was dropped on the CR-39 track detector. All the samples were irradiated with thermal neutrons in Am-Be neutron source with a thermal neutron fluence of about($3.0249x10^9 n.cm^{-2}$). Uranium content in water samples of the study area ranges from 7.9 to 19.12μg/l, the activities of ^{238}U,^{235}U and ^{234}U in taps water of Nineveh are in the range of9.75, 0.46 and 9.84mBq/l to 23.6, 1.1 and 23.8mBq/l respectively and the range of U_{nat} is from20.06 to 48.5mBq/l. The results of the annual effective dose (E_T) (μSv/y) of the uranium isotopes (^{238}U, ^{235}U, ^{234}U),ranged from 3.5, 1.7, 3.6, 7.3 in Talskuf to 8.6, 4.0, 8.6, 17.7 μSv/y in Hemam Al-Aleel respectively, with an overall average value 6.29±1.7μSv/y, 2.9±0.8, 6.4±1.7, 13±3.4 μSv/y respectively. The annual effective dose natural uranium in all water samples within the limit 7.3 to 17.7 μSv/y.

Key words: Uranium concentration values · Annual effective dose · Thermal neutrons fluence · Daily uranium intake

INTRODUCTION

Natural waters contain both α -emitters from uranium, (e.g. ^{238}U) and α-emitters from thorium (e.g. ^{224}Ra) radioactive decay series. The radionuclide concentrations in underground water depend on the kind of mineral surrounded, the chemical composition of the water, the water flow rate and the soil ions retention [1].

Man-made and natural sources of radiation are the cause of background radiation that human beings are continuously exposed to. The former results from various human activities, such as, nuclear events, reactor accidents, etc. The latter, on the other hand, is mainly composed of terrestrial and cosmic radiations. While the cosmic part of the background is the radiation from outer space that primarily consists of positively charged ions from protons to larger nuclei, the terrestrial part occurs naturally in the soil, water and air. There are quantitative differences observed for background radiation based on the geography and the geology of a location as well as the type of radioactive elements present in the surrounding (such as, potassium or the decay products of uranium, thorium, etc.). Consequently the long-living radionuclides in the earth's crust, cosmic rays, nuclear tests and the use of technological products all contribute to the increasing radiation level in our environment and about 82% of the world-wide average annual dose rate of 2.4 mSv is attributed to natural sources [2].

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. As a result, these

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radionuclides may enter the food chain through irrigation waters and the water supply through groundwater wells and surface water streams and rivers [3].

Trace particles of ^{238}U are found in most natural rocks. Uranium has affinity to some materials such as phosphates, coal, oil Shale etc. The soil and rocks dissolves radioactive elements, especially radium radon out of these rocks [4].

A study of the ^{238}U content in bottled water consumed in Kuwait was performed. The bottled water samples originated from 16 different countries. Of the 41 investigated samples, ^{238}U was detected in 23 samples in which the radionuclide's activity was determined. Consequently, it was found that activity levels of all samples were several of orders of magnitude below the guidance limits. Moreover, annual effective doses were estimated for three age groups, namely adults, children and infants. As a result, it was found that the doses received by all age groups were several of orders of magnitude below the guideline levels. Hence, consumption of bottled water sold in Kuwait is safe for the presence of ^{238}U [5].

The aim of the present investigations is to determine the concentrations and annual effective dose of uranium in drinking water used by people who live in Nineveh province in Iraq.

Gelogey of the Aeea: The area of Nineveh is located in northern Iraq and its capital city is Mosul and the geographic c oordinates of Mosul is between latitude 37° 1'45.51"N, longitude 42°21'40.14"E and latitude 35°25'12.78"N, longitude 42°47'31.17"E, while the height above sea level ranges between 202m-364m. Water samples were collected from approximately all regions of Nineveh as illustrated in Fig. 1.

Experimental Details: In the study area, 11 locations were chosen for analysis of uranium concentration in water samples from the northern sector at the Iraq of Nineveh province as shown in Fig. 1.

The water samples were collected from the hand pumps. The fission track registration technique was used for the analysis of uranium concentration in water samples.

A known volume of water samples with standard solution few drops (~ 2 drops) was dropped on CR-39 track detector, water droplets are allowed to evaporate on the detectors in dust free environment at normally room temperature. This leaves a thin residue of non-volatile constituents, the detector was then covered with a second piece of the detector on both sides and was put in a plate of paraffin wax at a distance of 5 cm from Am–Be neutron source with thermal fluence ($3.0249 x 10^9 n.cm^{-2}$), for registration of fission tracks of the detectors due to $^{235}U(n, f)$ reaction [6], after irradiation, the CR-39 detectors were etched in 6.25 N NaOH at temperature of60°C for 6 h, the detectors were then rinsed in distilled water and then dried. The developed fission tracks were scanned using an optical microscope at a magnification of (400X).

Uranium concentrations in the water samples were determined using the formula [7];

$$Ux = Us\ \rho x/\rho s\ Is/ Ix.Rs/ Rx \quad (1)$$

Where: The subscripts x and s stand for the unknown and the standard, respectively; U, is the uranium content; xx and xs are the densities of the fission tracks for the unknown and the standard samples, respectively; I: is the isotopic abundance ratio of ^{235}U to ^{238}U; and R: is the range of fission fragments in mg cm^{-2}. The correction factor (Rs/Rx) is taken to be unity. Similarly, taking (Is/Ix) as unity, equation (1) becomes [7].

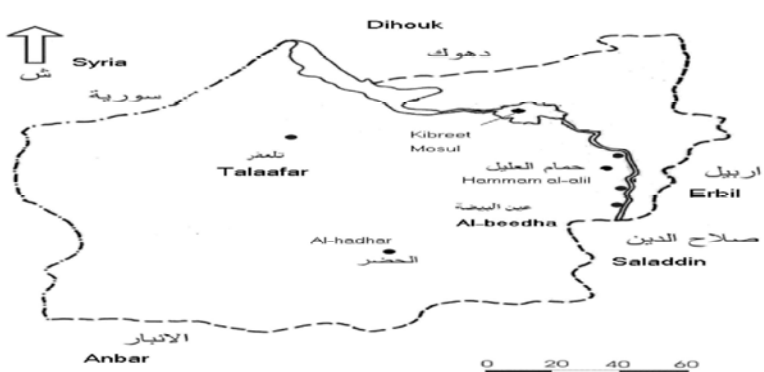

Fig. 1: Map of Nineveh province showing the area surveyed during the present Investigations.

Table 1: Radioactive properties of natural uranium isotopes[8]

Isotope	Isotope Half-life (year)	Specific activity (Bq/mg)	Isotopic abundance (%) By mass	By activity	Average energy per transformation (MeV/Bq) Alpha radiation	Beta radiation	Gamma radiation
$^{238}_{92}U$	4.51×10^{9}	12.44	99.274	48.2	4.26	0.010	0.001
$^{235}_{92}U$	7.1×10^{8}	80	0.7200	2.2	4.47	0.048	0.154
$^{234}_{92}U$	2.47×10^{5}	230700	0.0054	49.6	4.84	0.001	0.002

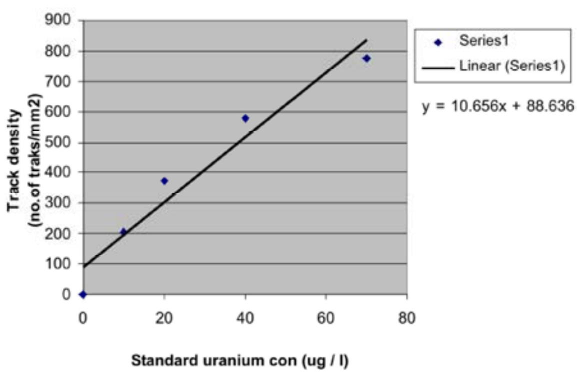

Fig. 2: Track density versus uranium concentration in standard samples[6]

$$Ux/Us = \rho x/xs \quad (2)$$

The relation of uranium concentration and track densities in standard samples are shown in Fig. 2.

The radioactive properties (half-life, specific activity, decay mode, etc.) of all uranium isotopes are however different. The total specific activity of natural uranium (i.e. the activity per unit mass of natural uranium metal) is 25.4 Bq/mg. The half-lives, specific activities, relative abundances and average energy per transformation of uranium isotopes ^{238}U, ^{235}U and ^{234}U in natural uranium are given in Table 1 [8].

Through the percentages listed in Table 1, the relation between specific activity and concentration can be calculated using equation below [8].

$$A\left(\frac{Bq}{L}\right)=\left(UC\left(\frac{mg}{L}\right)\times I.A.M(\%)\right)\times S.P.A\left(Bq/mg\right) \quad (3)$$

where: A-Activity (Bq/L), S.P.A- Specific activity, I.A.M- Isotopic abundance(%) by mass fraction

UC- Uranium concentration (mg/l), Specific Activity for ^{238}U=12.44 Bq/mg (IA%) =99.274 by activity=48.2, Specific Activity for ^{235}U=80 Bq/mg, (IA%) =0.720 by activity=2.2, Specific Activity for ^{234}U=230700 Bq/mg, (IA%) =0.0054 by activity= 49.6

Daily intake is estimate from the amount of a substance in food or drinking water, expressed on a body mass basis (usually mg/kg body weight), which can be ingested daily over a lifetime by humans without appreciable health risk.

Average over the whole population, is given by the international standard consumption rate of 1.4 l/d [9] and ICRP consumption rate of 2 l/d, so, for risk assessment a worst case value of 2 l/d [10].

The annual effective dose, E_T (Sv/y), to the adult members of the population can be given according to the equation [11]:

$$E_T(Sv/y)= e(g)(Sv/Bq)\times I(Bq/y) \quad (4)$$

E_T - Annual Effective dose, e(g) - Dose coefficients

The annual intake of uranium isotopes from drinking water for an adult consuming 2 l/d (I_{U238} (Bq/y),I_{U235} (Bq/y)andI_{U234} (Bq/y)) is considered by Eq.

$$I(Bq/y)=A(Bq/l)\times(365\times\text{consumption rate of water}) \quad 5)$$

As well Radiological impact of this radionuclide is calculated for the adult population using the following expression [12]:

$$D_w= C_w\times C_{Rw}\times Dc_w \quad (6)$$

$E_T = D_w$, $I_U= C_w\times C_{Rw}$, $e(g)= Dc_w$

where: D_w= Annual effective dose equivalent from consumption of water (Sv/y), C_w = The concentration of uranium in water (Bq /l), C_{Rw} = The consumption rate of water (l /y), consumption rate of water = 2 l/d[10], Dc_w= The dose conversion factor (Sv /Bq), e(g)=The dose coefficient in Sv/Bq.

By knowing that the e(g) of ^{238}U (Sv/Bq) is equal to 4.50E-08, e(g) of ^{235}U (Sv/Bq) is equal to 4.70E-08 and e(g) of ^{234}U(Sv/Bq) is equal to 4.90E-08 which are the ingestion dose coefficients for the ^{238}U, ^{235}U and ^{234}U radionuclide, respectively [13-14].

RESULTS AND DISCUSSION

The values of uranium concentration and daily uranium intake in water samples of the study area are presented in Table 2. Uranium content in water ranges from 7.9to 19.12 μg l^{-1} for Talskuf and Hemam Al-Aleel, respectively, with an average of 14.04±3.6μg l^{-1}. The International Commissionon Radiological Protection (ICRP, 1993) has recommended1.9μg l^{-1} of uranium in drinking water as the safe limit. The world health organization (WHO) has recommended 15 μg $l^{-1}$of uranium in water as safe limit for drinking purposes (2004).Recently, the United States Environmental Protection Agency (USEPA) has regulated uranium in public water supplies and has set the values of 30 μg l^{-1} as safe limits (2003). These levels are set to represent a concentration that does not result in any significant risk to health over a lifetime's drinking water. On comparing the uranium values in drinking water with the recommended value of ICRP and WHO, some samples seem to have uranium values more than the recommended level. However, when compared with US EPA the values are within the safe limits. Uranium concentration in some locations in Nineveh are shown in Fig. 3.

Table 2 and Fig. 4 show the results of daily uranium intake in the ranges from 15.8 to 38.24 μgl^{-1} for Talskuf and Hemam Al-Aleel, respectively, with an average of 28 ±7.4 μgl^{-1}, in which the average daily intake of uranium is high for some locations, but it remains within the limits recommended by EPA.

Uranium which is found in water considered as natural uranium and by knowing that the specific activity for natural Uranium is 25.4 Bq/mg [8] and also by including 3 types of uranium isotopes (which form the U_{nat}) which are ^{238}U, ^{235}U and ^{234}U, the activity can be calculated for these isotopes using the eq. 3 and information about the specific activity and mass fraction is given in table 1.Uranium isotopes activities in water samples collected from Nineveh are given in Table 3 and Figs. 5, 6, 7 and 8, which show that the activities of ^{238}U,^{235}U and ^{234}U in taps water of Nineveh are in the range of9.75, 0.46 and 9.84mBq/l to 23.6, 1.1 and 23.8mBq/l respectively and the range of U_{nat} is from20.06 to 48.5mBq/l.

The results of the annual effective dose (E_T) (μSv/y) of the uranium isotopes (^{238}U, ^{235}U, ^{234}U) and average total annual effective dose for drinking water are given in Table 4 and Figs. 9,10, 11, 12 that illustrate the annual

Table 2: Uranium Concentration and daily uranium intake in Drinking Water

Sample Code	Sample Location	Uranium Concentration μg/l	Daily uranium intake I_d (μg/d)
a1	Rabiaa	9.01	18.02
a2	Al-Sahel Al-Aemen	17.66	35.32
a3	Hemam Al-Aleel	19.12	38.24
a4	Al-Hamadania	11.65	23.3
a5	Talskuf	7.9	15.8
a6	Sanjar	12.4	24.8
a7	Al-Sahel Al-Aeser	18.15	36.3
a8	Al-Kayra	12.7	25.4
a9	Talaefar	13.9	27.8
a10	Sad Al-Mosul	18.61	37.22
a11	Zemar	13.39	26.78
	Average	14.04±3.6	28±7.4

Table 3: Activity of uranium isotopes in water

Sample Location	Activity for ^{238}U mBq/l	Activity for ^{235}U mBq/l	Activity for ^{234}U mBq/l	Activity for Un_{atm}Bq/l
Rabiaa	11	0.52	11.2	22.8
Al-Sahel Al-Aemen	21.8	1.02	22	44.7
Hemam Al-Aleel	23.6	1.1	23.8	48.5
Al-Hamadania	14.3	0.67	14.5	29.6
Talskuf	9.75	0.46	9.84	20.06
Sanjar	15.3	0.71	15.4	31.5
Al-Sahel Al-Aeser	22.4	1.05	22.6	46.1
Al-Kayra	15.68	0.73	15.8	32.2
Talaefar	17.16	0.8	17.3	35.3
Sad Al-Mosul	22.98	1.07	23.18	47.2
Zemar	16.53	0.77	16.68	34
Average	17±4.5	0.82±0.2	17.5±4.6	35.5±9.0

Table 4: Annual effective dose to the public during the year

Sample Location	E_T (μSv/y) ^{238}U	E_T (μSv/y) ^{235}U	E_T (μSv/y) ^{234}U	E_T (μSv/y) U_{nat}
Rabiaa	4.0	1.9	4.1	8.3
Al-Sahel Al-Aemen	7.9	3.7	8.0	16.3
Hemam Al-Aleel	8.6	4.0	8.6	17.7
Al-Hamadania	5.2	2.4	5.3	10.8
Talskuf	3.5	1.7	3.6	7.3
Sanjar	5.6	2.6	5.6	11.5
Al-Sahel Al-Aeser	8.1	3.8	8.3	16.8
Al-Kayra	5.7	2.7	5.8	11.8
Talaefar	6.2	2.9	6.3	12.9
Sad Al-Mosul	8.4	3.9	8.5	`17.2
Zemar	6.0	2.8	6.1	12.4
Average	6.29±1.7	2.9±0.8	6.4±1.7	13±3.4

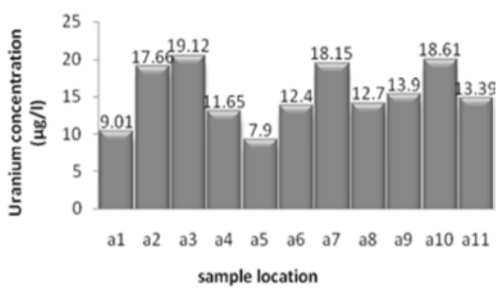

Fig. 3: The uranium concentration µg/l in water in some locations in Nineveh Province.

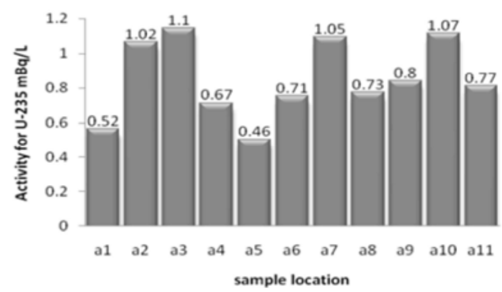

Fig. 6: The activities for ^{235}U mBq/l in water in some locations in Nineveh Province.

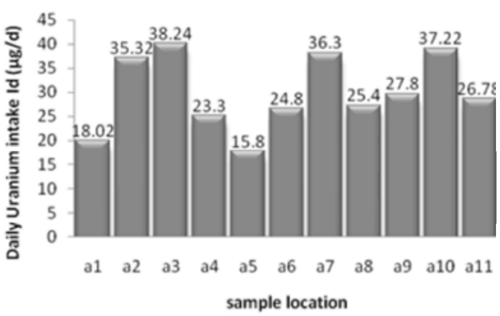

Fig. 4: The daily uranium intakes in water in some locations in Nineveh province.

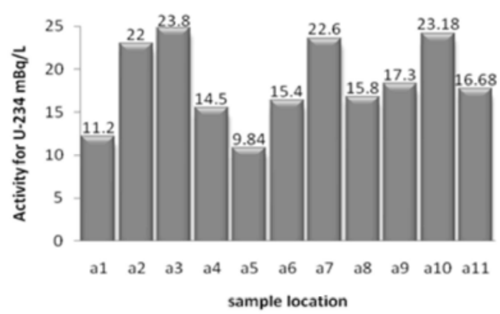

Fig. 7: The activities for ^{234}U mBq/l in water in some locations in Nineveh Province.

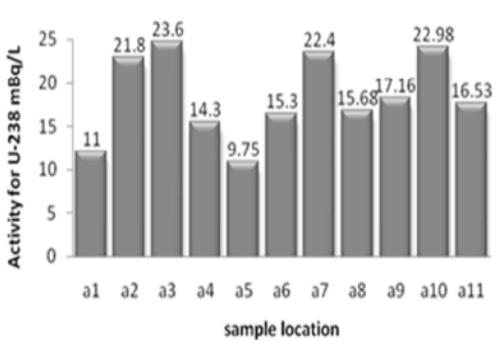

Fig. 5: The activities for ^{238}U mBq/l in water in some locations in Nineveh. province.

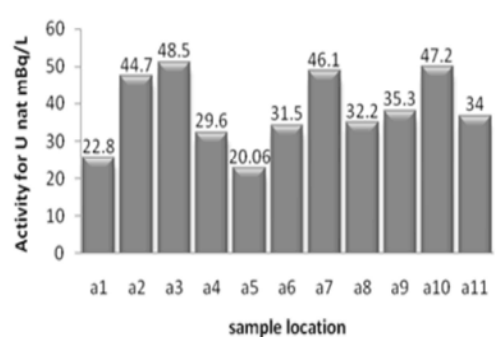

Fig. 8: The activities for U_{nat} mBq/l in water in some locations in Nineveh Province.

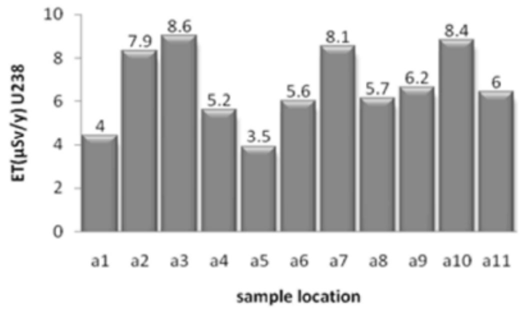

Fig. 9: The annual effective dose (E_T) (μSv/y) of the U^{238} in some locations in Nineveh Province.

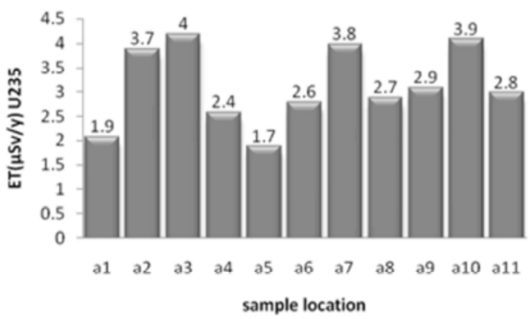

Fig. 10: The annual effective dose (E_T) (μSv/y) of the U^{235} in some locations in Nineveh province.

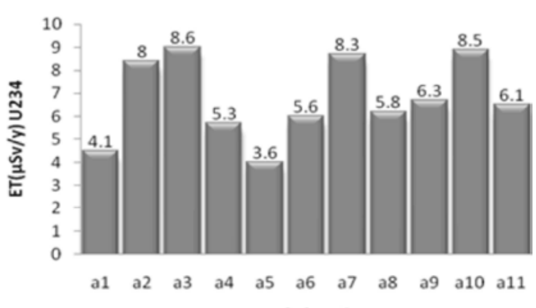

Fig. 11: The annual effective dose (E_T) (μSv/y) of the U^{234} in some locations in Nineveh Province.

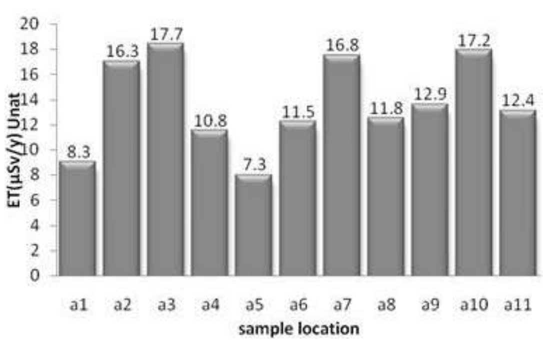

Fig. 12: The annual effective dose (E_T) (μSv/y) of the U_{nat} in some locations in Nineveh. Province.

effective dose from water to the adult members of the population in Nineveh residential districts ranged from 3.5, 1.7, 3.6, 7.3in Talskuf to 8.6, 4.0, 8.6, 17.7 μSv/y in Hemam Al-Aleel respectively, with an overall average value 6.29±1.7μSv/y, 2.9±0.8, 6.4±1.7, 13±3.4 μSv/y respectively. The annual effective dose natural uranium in all water samples were within the limit 7.3 to 17.7 μSv/y. The estimated radiological impact of 7.3 to 17.7 μSv/y is only a minor fraction of recommended ICRP annual effective dose of 1mSv and the global average annual radiation dose of 2.4 mSv to for humans from all natural radiation sources and is comparable with the global average ingestion dose 0.18 mSv/y due to these radionuclides [15].

However, one must bear in mind that the annual effective dose for the members of the public according to the ICRP recommendation is 1 mSv [15].

The limits of uranium concentrations in drinking water were given by several organizations and committees such as EPA, WHO, UNSCEAR and ICRP, which recommended the UC values as 30μg /l, 15μg /l, 9μg/l and 1.9μg/ respectively [16].

In the present investigation study, UC in drinking water of Nineveh province ranged from 7.9 to 19.12 μg/l, with an overall average value of 14.04±3.6 μg/l. The values of UC in all water samples were more than the recommended value of ICRP (1.9 μg/l), but most of the values are comparable or less than the safe limit of WHO (15 μg/l), United States EPA (30 μg /l) and UNSCEAR recommended safe limit (9 μg /l) [16].

The UC, daily intake, activity uranium isotope and annual effective dose of uranium in water used for drinking in Nineveh is within the permissible limits and on this basis, the higher annual effective dose for natural uranium were for Hemam Al-Aleel water.

CONCLUSION

Uranium content in water ranges from 7.9 to 19.12 μg l^{-1} for Talskuf and Hemam Al-Aleel, respectively, with an average of 14.04±3.6μg l^{-1}. The values of uranium concentration in water samples are more than the recommended value of 1.9 μg l^{-1}(ICRP, 1993). However, when compared with WHO and USEPA the values are within the safe limits. The high uranium content in Hemam Al-Aleel water samples may be due Sulphurous richness.

The uranium concentration, daily intake, activity of uranium isotope and annual effective dose of uranium in Hemam Al-Aleel water is higher than other regions of water and this is due to the high Sulphurous rate in water.

REFERENCES

1. Dogru M. and Canbazoglu, 2002. Natural gross radioactivity in various surface and tap waters in Elazig Turkey, J. Radioanal Nucl. Chem., 254(2): 379-382.
2. Yaicin, P., H. Taskin E. Kam H. Taskin M. Terzi, A. Varinlioglu, A. Bastug and Tasdelen, 2012. Investigation of radioactivity level in soil and drinking water samples collected from the city of Erzincan, Turkey, J. Radioanal Nucl. Chem., 292: 999-1006.
3. Abdullah K.M..S and M.T. Ahmed 2012. Environmental and Radiological pollution in Creek Sediment and water from Duhok, IRAQ, The Nucleus, 49(1): 49-59.
4. Al-Bataina, B.A., A.M. Ismail, M.K. Kuttab, K.M. Abumurad and H. Mustafa, 1997. Radon measurements in different types of Natural waters in Jordan, Radi. Meas., 28(1-6): 591-594.
5. Alrefae, T., 2012. Investigation of ^{238}U content in bottled water consumed in Kuwait and Estimates of annual effective doses, Health Physics, 102(1): 85-89.
6. Tawfiq, N.F., 2013. Uranium and radon concentration in ground water in Aucashat city (Iraq) and the associated health effects, Adv. Appl. Sci. Res., 4(3): 167-171.
7. Fleischer, R.L., P.B. Price and R.M. Walker, 1975. Nuclear Tracks in Solids, Principles and Applications. University of California Press, Berkeley, (USA).
8. Shafik Shakier Shafik, Bushra Ali Ahmed and Mazin Mohammed, (2014). Determination Uranium Concentrations and Effective Dose of Drinking Water for Nineveh Governorate-Iraq, Using Kinetic Phosphorescence Analyzer (KPA), Journal of Environmental Protection, 5: 200-206.
9. United Nations Sources and Effects of Ionizing Radiation (UNSCEAR). 2000. Report to the General Assembly with Scientific Annexes, pp: 126-127, United Nations, New York.
10. International Commission on Radiological Protection (ICRP) (1975). Report of the task group on Reference Man, ICRP Publication 23; Pergamon Press, Oxford, UK.
11. International Atomic Energy Agency (IAEA) 2007. “Management of Reprocessed Uranium Current Status and Future Prospects”, IAEA publication.
12. Alam, M.N. Chowdhry, M. Kamal, S. Ghose, M.N. Islam and M. Awaruddin, 1999. Radiological assessment of drinking water of the Chittagong region of Bangladesh, Radiat. Prot. Dosim. 82: 207-214.
13. Wrenn, M.E., P.W. Durbin, B. Howard, J. Lipsztein, J. Rundo, E.T. Still and D.L. Willis, 1985. "Metabolism of ingested uranium and radium", Health Phys., 48: 601-633.

14-. Khan, F.M. Williams and Wilkins, 1984. "The physics of radiation therapy" Baltimore, USA.

15. International Commission on Radiological Protection (ICRP), 1990. “Recommendations of the International Commission on Radiological Protection”, ICRP Publication, 21: 1-3.
16. Addendum to Volume 2: (1998) Health criteria and other supporting information WHO, Geneva, Switzerland.