Evaluation of Gross Alpha and Beta Activity Concentrations and Annual Effective Dose in Drinking Waters of Misan Province-Iraq Using Low Background Gas Flow Proportional Counter (LB- 4110)

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Abstract

In this study, assessment of levels natural radioactivity in drinking water samples of Misan Province of Iraq was carried out. A total of 33 (Tigris river, station and Tap) water samples collected from eleven places in Misan Province of Iraq. The beta and alpha gross radioactivity of the samples water was measured and an average annual effective dose derived of drinking-water ingestion was estimation utilizing new model a LB-4110 low background gas flow proportional counter. The data indicated that the Beta and Alpha gross activities and annual effective dose in samples did not exceed WHO recommended levels (0.5 Bq/L of Alpha gross, 1.0 Bq/L of Beta gross and 0.1 mSv/y for annual effective dose).

Key Words: Drinking Water, Gross Beta, Gross Alpha Dose Intake, Misan Province.

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Introduction

Drinking water has witnessed a remarkable attention in recent years (Miao et al, 2013). The most important parameter is water quality in environmental studies and the radioactivity presented in surface water is mainly coming from the radioactive elements in the earth's crust (Najib et al, 2014). Mostly, radioactivity of drinking water presents in the form of the sum of Alpha and Beta emitters. As example Alpha emitters such (^{210}Po, ^{226}Ra and ^{238}U) and Beta emitters like (^{40}K, ^{228}Ra and ^{210}Pb). Natural isotopes eg 40K and the 238U and 232Th series nuclides are important sources of external and internal exposure to humans. Among the nuclides of terrestrial origin are the radionuclides, which mainly enter the human body by the intake of water and food, including 40K, ^{238}U and ^{232}Th. It causes many dangerous and health problems for humans due to the presence of radionuclides in the water, especially when drinking water precipitates and enters the human body. These radionuclides, which are dissolved in the body, are emitted in the form of particles (alpha and beta) and photons (gamma), which gradually interact with living tissues (Gruber et al, 2009; Ogundare et al, 2015).

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Therefore, it is significant to estimation the quantity of radioactivity in water for every location where reside people, thus as to guard against its deleterious affects (W.H.O, 2006). The main aim of the study are to estimate the grosses Beta and Alpha radioactivity in drinking water samples (Surface water of Tigris river, station water and Tap water) indicated from eleven regions of Misan Province, and too estimation annual effective dose of the general public. Finally, data will provide a data base line that utilized to estimate probable changes the future.

Methods and Materials

1. The Study Area

In this work, we are going to study the area which located in the south of Iraq called Misan Province, as shown in figure1. However, the latitudes for this area fall between 31° 30′.0″N to 33°0′.00″N and Longitudes between 46° 30′. 0″E to 47° 30′. 0″E, as seen in figure 2. While, this covers an area of 16072 km^{2}approximately. The residents in Misan Province depends on, Tigris river, stations and taps as their water drinking sources. Based on that, the above cause shows it is necessary to apply like this study to determine the basic radioactivity levels that avail as reference result of the future researches.

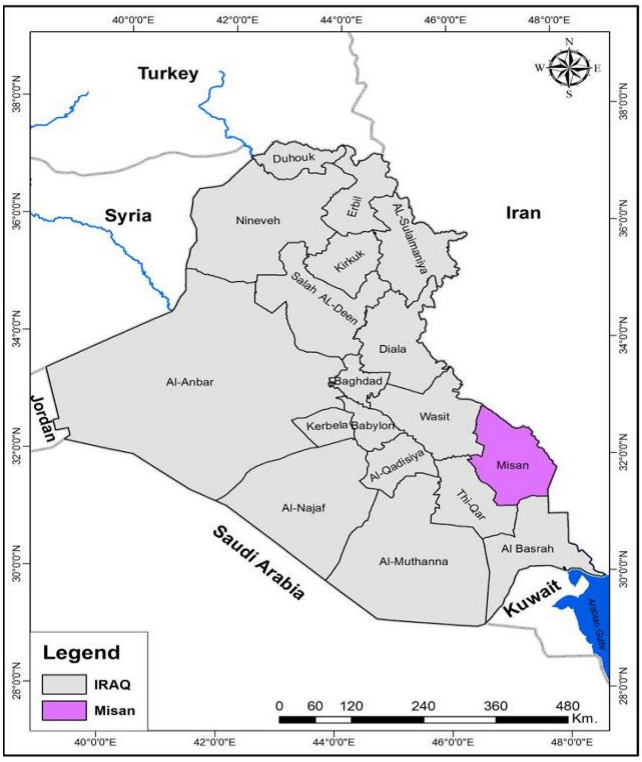

Fig. 1. Map administrative divisions of Iraq showing the study area

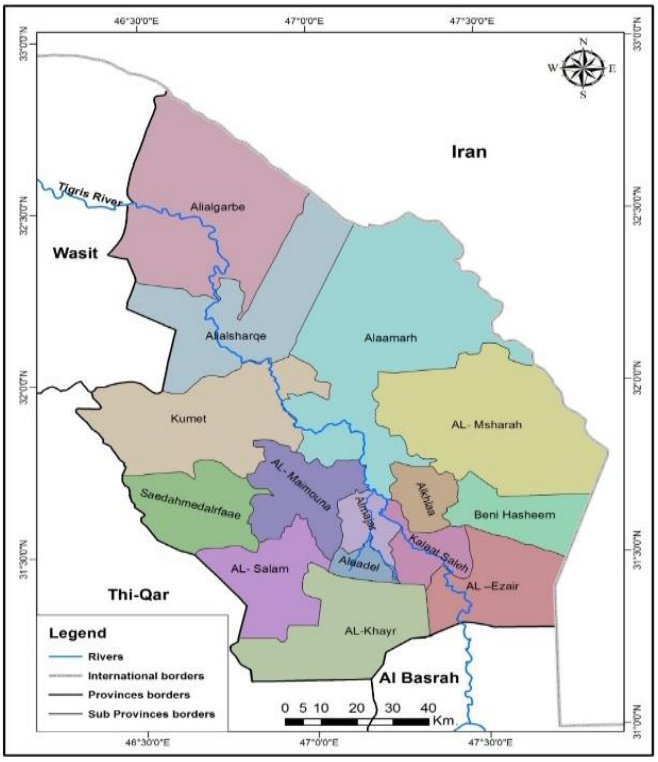

Fig. 2. Map administrative divisions of the study area

2. Sample Collection and Preparation

In the current research, a total of Thirty-three (Tigris river, station and Tap) samples of water were collected from the cities of (Alialgarbe), (Alialsharqe), (Kumet), (Alaamarh), (A-Msharah), (Alkhlaa), (Al-Maimouna), (Al-Salam), (Almajar), (Kalaat Saleh) and (Al-Ezair) in Misan Province. Eleven samples each were collected from Tigris river water, eleven samples of stations water, eleven samples, taps water. The samples of water were collected and the point of each sample is collected and gives a unique code after noted by its G.P.S coordinate which taken by a handheld G.P.S device as shown in figure 3, figure4 and figure 5. The samples of water were collected in 2-litre plastic containers vail 1% air space left for thermal expansion (Avwiri et al, 2016). The water samples at the time of collection were acidified by about nitric acid 20ml per liter to reduce the pH to 2. However, we apply this to minimize precipitation of the radionuclide present in the sample water and too to prevent the absorption of radioactivity by walls of the sample container (I.S.O,1992). The sample containers were then labeled and taken to the laboratory for analysis. These samples were Preparation and analysis for Beta and Alpha grosses activities using a LB-4110 model low back-ground gas flow proportional counter at Center for

Radiation Protection (CRP), Ministry of Environment, Baghdad, Iraq. In the laboratory, take a glass beaker 50ml weigh it using sensitive balance. Filter 30 ml from the sample then put it in the glass beaker then dry it to dryness. Leave the beaker to cold then weigh it again and calculate the sample net weigh. Using the dilution equation to calculate the sample volume which give 100 m gm as a final weigh. Put the Sample in the beaker and dry it to dryness. Add 3ml from nitric (1normaly) to the beaker and to remove all the solid material in the sample. Put the sample in the planchet which is weigh before using additional material to dryness. Put the sample in the oven 105 c^0 for two hours. Put the sample in the desiccators for cold then weigh the sample and return it to the desiccators to the measurement time. Gross Beta will be measure directly using GPC. Sample will be heated in the oven a gain then will return to the desiccators for 72 hours. Sample weigh will be measure again before measurements. Gross Alpha count will be measure directly using GPC (ASTM, 1992).

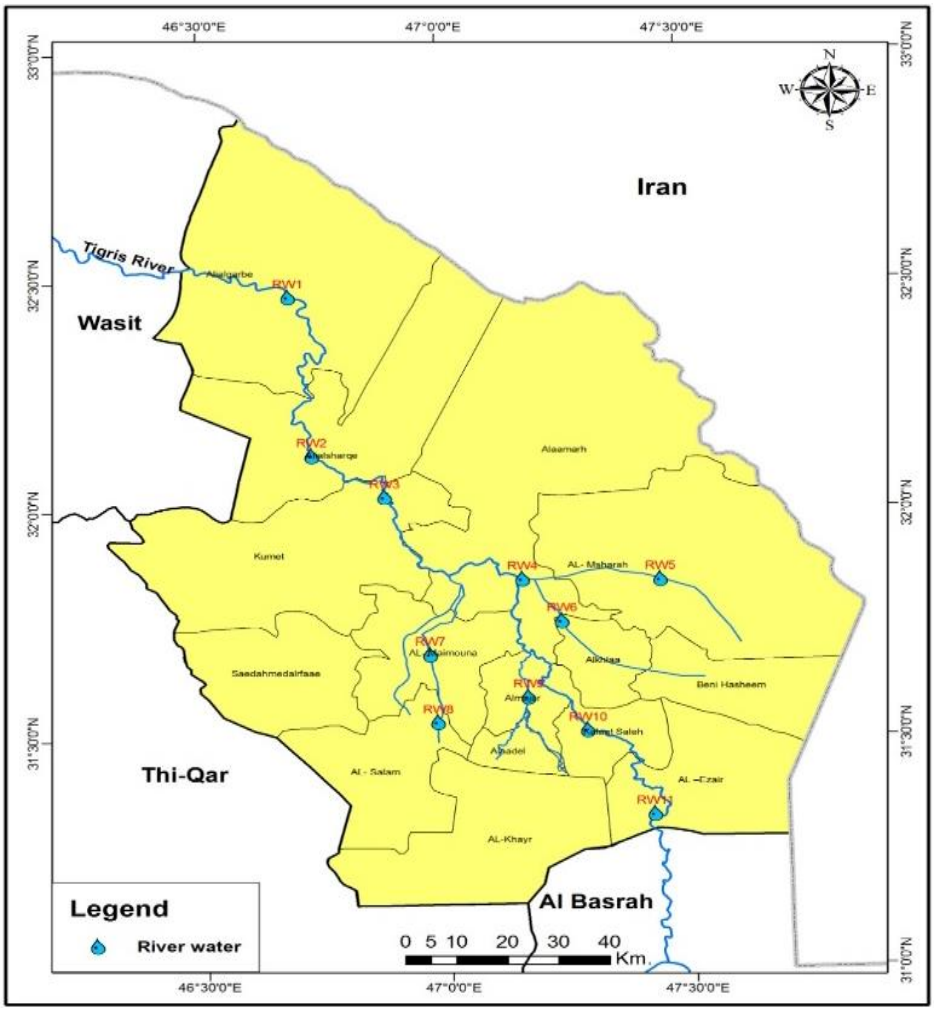

Fig. 3. Map administrative divisions of the study area showing locations of Tigris water Samples

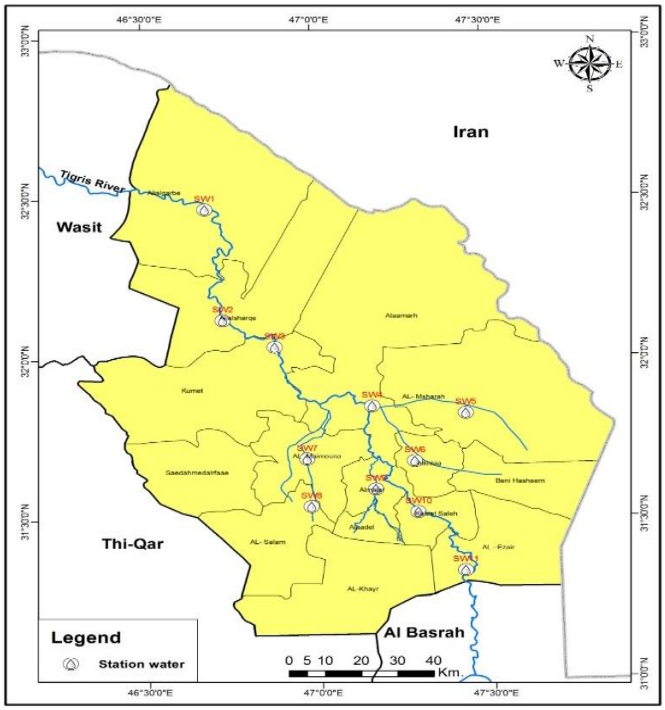

Fig. 4. Map administrative divisions in the current study area which shows the locations of Station water Samples

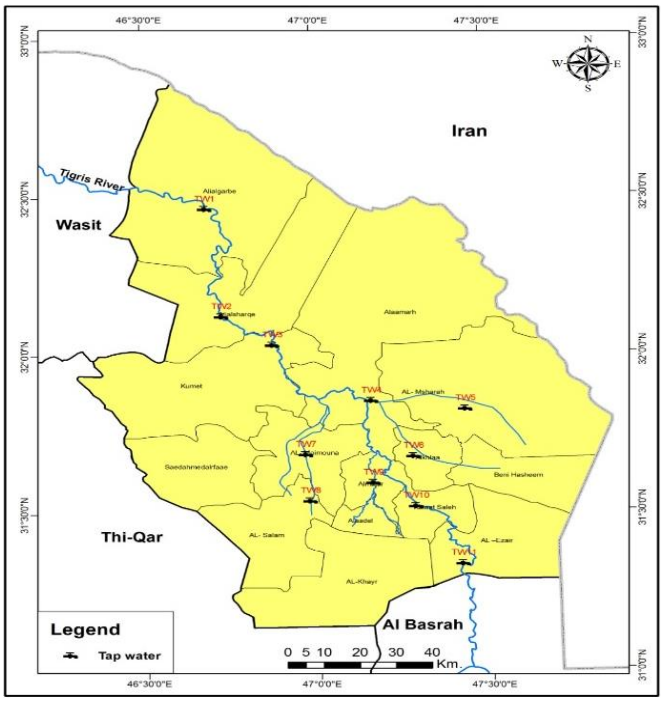

Fig. 5. Map administrative divisions of the study area showing locations of Tap Water Samples

3. Counting Equipment

The low background gas flow-proportional counter (LB-4100) four channel Alpha and Beta counter at Center for Radiation Protection (CRP), Ministry of Environment, Baghdad was utilized of counting. Moreover, all the counter channel have a window thick-ness of 80 $\mu g/cm^3$ and diameter of 2.25inch. The chambers are covered by lead to prevent part of ambient gamma rays of entering the environment measuring. The system is connected to a microprocessor loaded with a spreadsheet program (OSUM). The system can be operated at a bias voltage 1500V with P-10 counting gas (10% Methane, 90% Argon Mixture) (User's Manual, 2003).

4. Detector Calibration

standard Alpha used for this work was ^{241}Am which have 432 years as half-life, While the Beta standard was ^{90}Sr whose half-life is 28 years. The particles Beta and Alpha were utilized its standards to calibrate the low back-ground gas flow-proportional counter (LB-4100).

Beta and Alpha activities in Becquerel's per Litter were estimation utilizing the expression (Avwiri et al, 2016):

$$(\alpha/\beta)(Bq/l)\text{Activity} = \frac{\text{Rate counting } (\alpha,\beta) - \text{rate Backgoundcounting } (\alpha,\beta)}{\text{Sample Efficiency} \times \text{channel efficiency} \times \text{weight of the sample}} \quad (1)$$

5. The Annual of Effective Dose Estimation

Human body gets exposure of water drinking due to naturally happening radionuclide of uranium and thorium series in water, no matter how small the total exposure in the contribution of drinking water, because there is a relationship between this type of exposure and deleterious radiological health effects. A dose level of committed effective dose is 0.1 mSv/year ingestion of water as recommended in (WHO, 2011). The equation (2) was used to calculate (A.E.D) annual effective dose associated by radiation exposure by ingestion of several kind of water drinking in Misan province.

$$A.E.D = A \times V \times C \quad (2)$$

Results and Discussion

1. Alpha and Beta Gross Activities in Drinking Water of Misan Province

The analyses for the samples water got three sources of drinking waters were considered as Tigris river water, station water, and tap water sources as appear in Table 1, Table 2 and Table 3.

The activity for the Alpha gross in Tigris river water samples ranged from 0.083Bq/L(Al-Ezair) to 0.17Bq/L(Kumet) or 0.17Bq/L(Alkhlaa) as average of 0.126±0.029 Bq/L. While, the activity for the Betagross ranged from 0.21Bq/L(Alaamarh) to 0.68 Bq/L(Al-Maimouna) as average of 0.469±0.165Bq/L, as seen intable 1 and figure 6.

However, the activity for Alpha gross in station water samples ranged from 0.054Bq/L (Al- Msharah) to 0.21Bq/L (Almajar) or 0.21Bq/L (Kalaat Saleh)as average of 0.149±0.047 Bq/L. While, the activity for Betagross ranged from 0.34Bq/L(Alkhlaa) to 0.64Bq/L(Al-Salam) or 0.64Bq/L(Almajar) or 0.64Bq/L(Al-Ezair) as average of 0.55±0.095Bq/L, as seen in table 2 and figure 7.

As last samples in tap water, the activity for the Alphagross ranged from 0.095Bq/L(Alaamarh) to 0.21Bq/L(Al- Msharah) or 0.21Bq/L(Al-Ezair) as average of 0.150±0.041Bq/L . While, the activity Beta gross ranged from 0.31Bq/L(Al-Maimouna) or 0.31Bq/L(Al-Salam) to 0.62 Bq/L(Alialsharqe) as average of 0.482±0.120 Bq/L, as shown in table 3 and figure 8.

The study data appear that all the values of the Beta and Alpha gross activities in all samples drinking water (Tigris river, station and tap) were below recommended the maximum contamination values WHO of 0.5 Bq/L for Alpha gross and 1.0 Bq/L for Beta gross (WHO, 2011).

Table 1. Result of Alpha and Beta Gross Activities of Samples Tigris River Water

Code of Tigris River water Sample	Sample Location	Geographical	Location	Alpha Gross Activity (Bq/L)	Beta Gross Activity (Bq/L)
RW_1	Alialgarbe	32° 28′15.6″ N	46° 41′06.5″ E	0.13	0.42
RW_2	Alialsharqe	32° 07′23.7″ N	46° 43′41.8″ E	0.15	0.47
RW_3	Kumet	32° 01′53.8″ N	46° 52′40.8″ E	0.17	0.5
RW_4	Alaamarh	31° 50′57.6″ N	47° 09′35.8″ E	0.092	0.21
RW_5	Al- Masharah	31° 49′23.4″ N	47° 26′15.1″ E	0.14	0.61
RW_6	Alkhlaa	31° 45′05.9″ N	47°13′24.4″ E	0.17	0.63
RW_7	Al-Maimouna	31° 41′11.5″ N	46° 57′57.6″ E	0.107	0.68
RW_8	Al-Salam	31° 32′18.3″ N	46° 58′46.8″ E	0.14	0.27
RW_9	Almajar	31° 35′29.7″ N	47° 09′59.5″ E	0.11	0.61
RW_{10}	Kalaat Saleh	31° 31′03.8″ N	47° 17′16.5″ E	0.103	0.52
RW_{11}	Al-Ezair	31° 19′58.8″ N	47° 25′20.8″ E	0.083	0.24
	Mean Value			0.126±0.029	0.165±0.469
	WHO limit	(WHO, 2011)		0.5	1

Table 2. Result of Alpha and Beta Gross Activities of Samples Station Water

Code of Station water Sample	Sample Location	Geographical	Location	Gross Alpha Activity (Bq/L)	Gross Beta Activity (Bq/L)
SW_1	Alialgarbe	32° 28′03.3″ N	46° 40′57.3″ E	0.12	0.47
SW_2	Alialsharqe	32° 07′18.4″ N	46° 43′46.5″ E	0.17	0.63
SW_3	Kumet	32° 02′11.5″ N	46° 52′46.8″ E	0.11	0.62
SW_4	Alaamarh	31° 50′58.4″ N	47° 09′37.2″ E	0.18	0.53
SW_5	Al- Masharah	31° 49′29.4″ N	47° 25′59.3″ E	0.054	0.51
SW_6	Alkhlaa	31° 40′39.2″ N	47°16′52.5″ E	0.15	0.34
SW_7	Al-Maimouna	31° 41′11.8″ N	46° 58′02.7″ E	0.14	0.52
SW_8	Al-Salam	31° 32′19.4″ N	46° 58′40.9″ E	0.18	0.64
SW_9	Almajar	31° 35′25.0″ N	47° 09′56.8″ E	0.21	0.64
SW_{10}	Kalaat Saleh	31° 31′05.2″ N	47°17′16.2″ E	0.21	0.51
SW_{11}	Al-Ezair	31° 20′04.0″ N	47° 25′16.4″ E	0.12	0.64
	Mean Value			0.149±0.047	0.095±0.55
	WHO limit	(WHO, 2011)		0.5	1

Table 3. Result of Alpha and Beta Gross Activities of Samples Tap Water

Code of Tap water Sample	Sample Location	Geographical	Location	Gross Alpha Activity (Bq/L)	Gross Beta Activity (Bq/L)
TW_1	Alialgarbe	32° 27′49.8″ N	46° 41′06.1″ E	0.17	0.57
TW_2	Alialsharqe	32° 07′23.5″ N	46° 43′44.2″ E	0.19	0.62
TW_3	Kumet	32° 01′54.4″ N	46° 52′36.4″ E	0.15	0.61
TW_4	Alaamarh	31° 51′10.0″ N	47° 09′44.1″ E	0.095	0.34
TW_5	Al- Msharah	31° 49′25.6″ N	47° 26′13.0″ E	0.21	0.51
TW_6	Alkhlaa	31° 40′35.1″ N	47°16′55.9″ E	0.11	0.6
TW_7	Al-Maimouna	31° 41′04.6″ N	46° 58′04.2″ E	0.12	0.31
TW_8	Al-Salam	31° 32′16.2″ N	46° 58′44.0″ E	0.12	0.31
TW_9	Almajar	31° 35′37.0″ N	47° 09′47.6″ E	0.17	0.52
TW_{10}	Kalaat Saleh	31° 31′05.0″ N	47°17′10.6″ E	0.11	0.409
TW_{11}	Al-Ezair	31° 20′04.3″ N	47° 25′10.3″ E	0.21	0.51
	Mean Value			0.150±0.041	0.482±0.120
	WHO limit	(WHO, 2011)		0.5	1

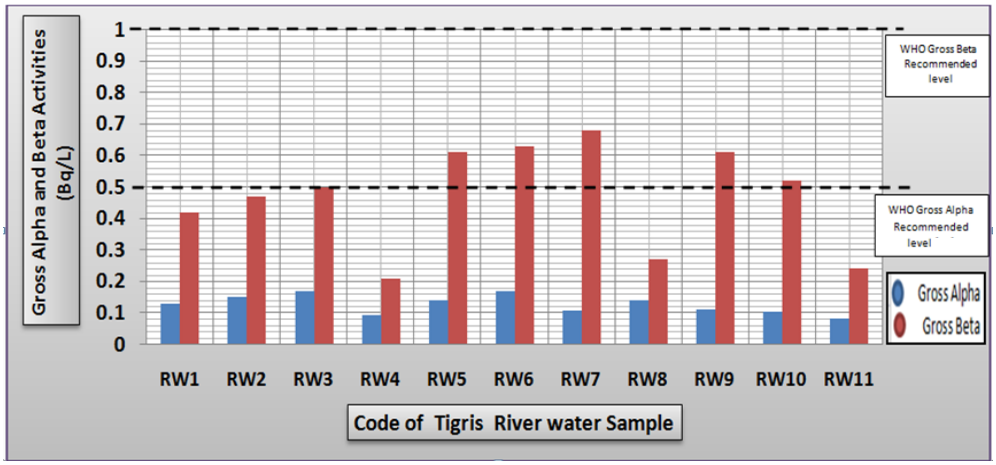

Fig. 6. The Beta and Alpha gross activities in Samples Tigris River Water

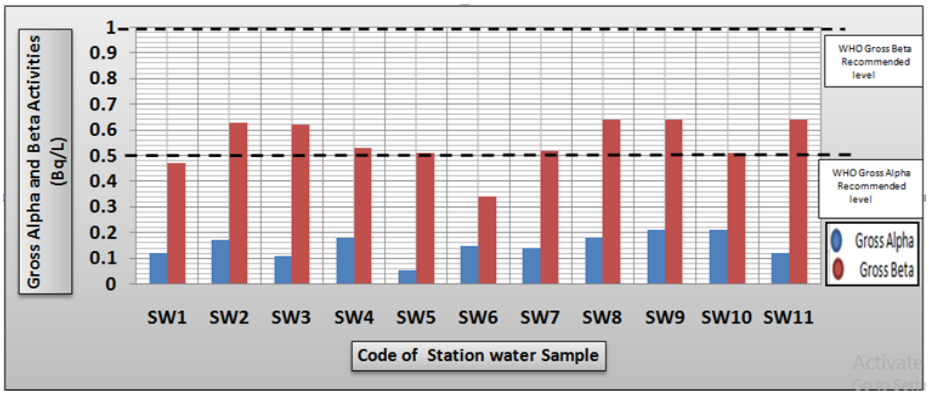

Fig. 7. The Beta and Alpha gross activities in Samples Station Water

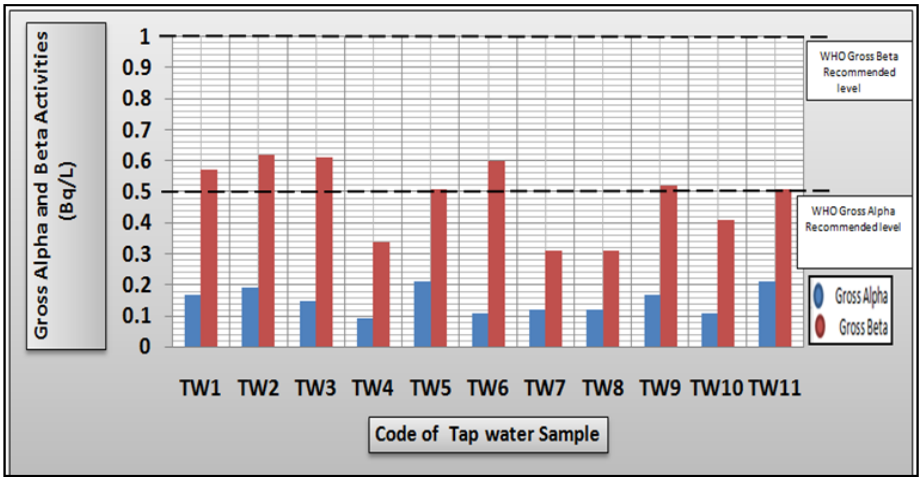

Fig. 8. The Beta and Alpha gross activities in Samples Tap Water.

2. Annual Effective Dose Due to Gross Alpha in Drinking Water of Misan Province

The estimated annual affective dose due to gross Alpha in samples of drinking waters (Tigris river water, station water, and tap water) are shown in Table 4-6.

The annual affective dose due to Alpha gross in Tigris river water samples ranged from 0.021 mSv/y(Al-Ezair) to 0.044 mSv/y(Kumet) or 0.044 mSv/y(Alkhlaa) as average of 0.033±0.007mSv/yas seen in table 4and figure 9.

The annual effective dose due to gross Alpha in samples station water ranged about 0.014 mSv/y (Al- Msharah) to 0.054 mSv/y (Almajar) or 0.054 mSv/y (Kalaat Saleh) as average of 0.039±0.01 mSv/y as seen in table 5 and figure 10.

Lastly, the annual affective dose due to Alpha gross in samples tap water ranged about 0.024 mSv/y (Alaamarh) to 0.054 mSv/y (Al-Msharah) or 0.054 mSv/y (Al-Ezair) as average of 0.039±0.01mSv/y as seenin table 6 and figure 11.

Data indicated that all the values of the annual affective dose in all samples drinking water (Tigris river water samples, station water samples and tap water samples) of Misan provinces were below recommended the value reference WHO of 0.1 mSv/y (WHO, 2011).

Table 4. Result of Annual affective Dose Due to Alpha Gross in Tigris River Water Samples

Code of Tigris River water Sample	Sample Location	Annual affective Dose Due to Alpha Gross (mSv/y)
RW_1	Alialgarbe	0.033
RW_2	Alialsharqe	0.039
RW_3	Kumet	0.044
RW_4	Alaamarh	0.024
RW_5	Al- Masharah	0.036
RW_6	Alkhlaa	0.044
RW_7	Al-Maimouna	0.027
RW_8	Al-Salam	0.036
RW_9	Almajar	0.028
RW_{10}	Kalaat Saleh	0.026
RW_{11}	Al-Ezair	0.021
	Mean Value	0.033±0.007
WHO limit	(WHO,2011)	0.1

Table 5. Result of Annual affective Dose Due to Gross Alphain Station Water Samples

Code of Station water Sample	Sample Location	Annual affective Dose Due to Alpha Gross (mSv/y)
SW_1	Alialgarbe	0.031
SW_2	Alialsharqe	0.044
SW_3	Kumet	0.028
SW_4	Alaamarh	0.047
SW_5	Al- Masharah	0.014
SW_6	Alkhlaa	0.039
SW_7	Al-Maimouna	0.036
SW_8	Al-Salam	0.047
SW_9	Almajar	0.054
SW_{10}	Kalaat Saleh	0.054
SW_{11}	Al-Ezair	0.031
	Mean Value	0.039±0.01
WHO limit	(WHO,2011)	0.1

Table 6. Result of Annual Effective Dose Due to Alpha Gross Samples Tap Water.

Code of Tap water sample	Sample Location	Annual affective Dose Due to Alpha Gross (mSv/y)
TW_1	Alialgarbe	0.044
TW_2	Alialsharqe	0.049
TW_3	Kumet	0.039
TW_4	Alaamarh	0.024
TW_5	Al- Msharah	0.054
TW_6	Alkhlaa	0.028
TW_7	Al-Maimouna	0.031
TW_8	Al-Salam	0.031
TW_9	Almajar	0.044
TW_{10}	Kalaat Saleh	0.028
TW_{11}	Al-Ezair	0.054
	Mean Value	0.039±0.01
WHO limit	(WHO,2011)	0.1

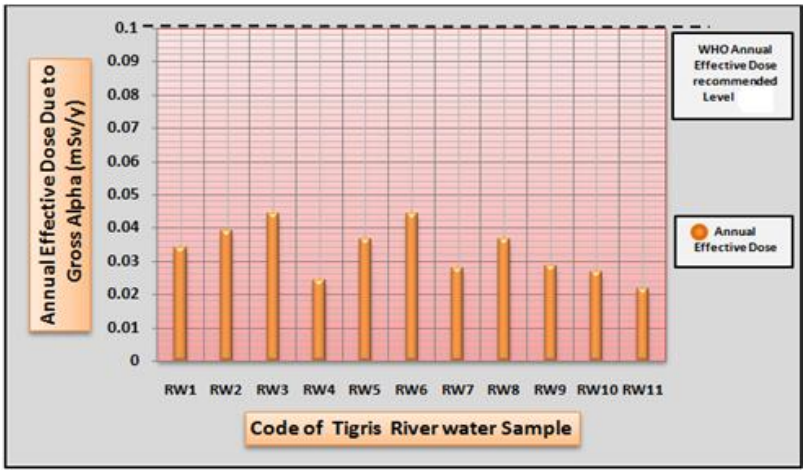

Fig. 9. The annual affective dose due to Alpha gross in Tigris Samples River Water

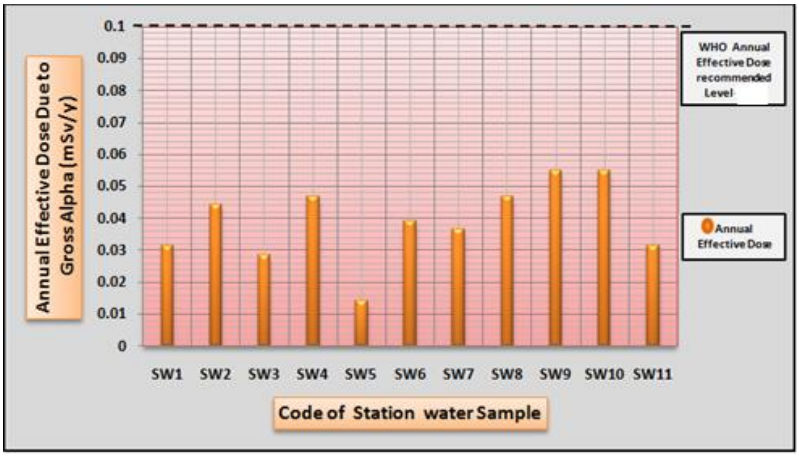

Fig. 10. The annual affective dose due to Alpha gross in Sample Station Water

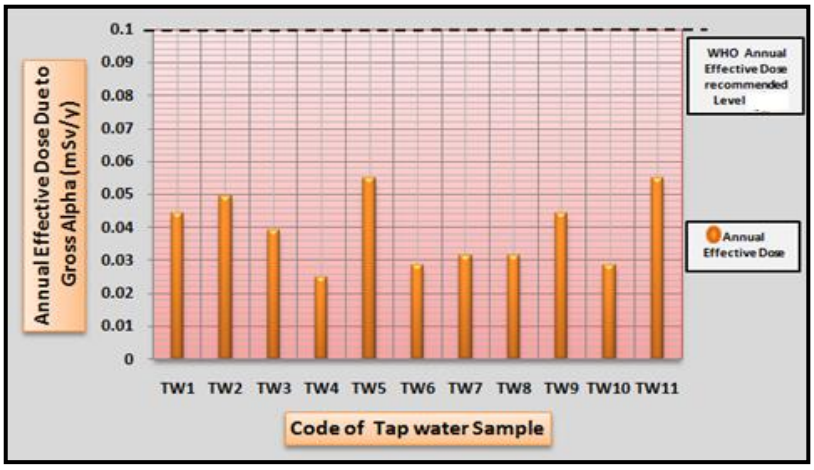

Fig. 11. The annual affective dose due to Alpha gross in Samples Tap Water

3. Comparison of Results

Data Beta Alpha gross activities conc. of drinking water measured in the study area that compare by the alike measurements made in other countries (table 7).

The gross aand bactivity concentrations measured in this study were compared with the similar measurements made elsewhere in the world The gross aand bactivity concentrations measured in this study were compared with the similar measurements made elsewhere in the world that appear in Table 7, the Alpha Beta gross activity conc. in Tigris river water were higher than those measured in China (Xiaoqing River, Jinan City) (Wang et al, 2015), but lower than those in Malaysia (Kelantan River Basin) (Hamzah et al, 2011), Nigeria (Western Niger Delta) (Agbalagba et al, 2012).

Beta and Alpha gross activities concentrations in water tap were higher than those measured in Turkey (Eastern Black Region Sea) (Damala et al, 2006), Bangladesh (Dhaka city) (Ferdous et al, 2012), China (Seven provinces) (Miao et al, 2013), Albania (Cfarku et al, 2014) Turkey (Rize Province) (Akbulut et al, 2015), but lower than those in Italy (Forte et al, 2007).

Table 7. Comparative of the gross Alpha, Beta activity conce data of this Study and other studies from several countries

Country and Place	Kind of Water	Gross Alpha Activity (Bq/L)	Gross Beta Activity (Bq/L)	Ref.
Eastern Black Sea Region, Turkey	Tap water	0.0002-0.015	0.0252-0.2644	Damla et al, 2006
Italy	Tap water	0.008-0.349	0.025-0.273	Forte et al, 2007
Kelantan River Basin, Malaysia	River water	0.39-6.42	0.66-16.18	Hamzah et al, 2011
Western Niger Delta, Nigeria	River water	0.02-35.1	0.7-151.2	Agbalagba et al, 2012
Bangladesh, Dhaka city	Tap water	0.00188-0.00816	0.0293-0.1157	Fedous et al, 2012
China, Seven provinces	Tap water	0.010-0.169	0.045-0.327	Miao et al, 2013
Albania	Tap water	0.036	0.269	Farku et al, 2014
Rize Province, Turkey	Tap water	0.022	0.085	Akbulut et al,2015
Xiaoqing River, Jinan City, China	River water	0.02-0.17	0.09-0.23	Wang et al, 2015
Misan Province, Iraq	River water Station Water Tap water	0.083-0.17 0.054-0.21 0.095-0.21	0.21-0.68 0.34 -0.64 0.31- 0.62	This Study

Conclusion

In this research, through drinking water samples, the active beta and alpha gains were embodied (Tigris river, station and tap) collected from the different areas in Misan Province were estimated utilized the Low Background gas flow-proportional counter (LB-4100). The data showed that, samples of water drink in study the area got low radioactivity

and all data measured are below the World Health Organization, the guideline for water of drink values of 1.0 Bq/L of Beta gross activity and 0.5 Bq/L value of Alpha gross activity. Moreover, the annual effective dose due to Alpha gross activity in samples drinking water was calculated. These results indicated that the calculated annual affective dose values in all the drinking water samples in the study area were show at safe level and were below the recommended value (0.1 mSv/y). Hence, study the area of drinking water (Misan Province) is radioactively safe to utilized and does not pose any health burden to the population. Finaly, the results in this study may of use to set radiation back-ground baselines in these areas and could help to create a public awareness about Beta and Alpha grosses activities in drinking water and the radiological effect on the dweller's health.

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References

Avwiri GO, Osimobi JC, Ononugbo CP. Gross alpha and gross beta activity concentrations and committed effective dose due to intake of water in solid mineral producing areas of Enugu State, Nigeria. *International Journal of Physics and Applications* 2016; 8(1): 33-43.

(American Society for Testing Materials) ASTM (1992), Annual Book of ASTM Methods .11.02, Philadelphia, U.S.A, 425-427.

Agbalagba EO, Avwiri GO, Chad-Umoreh YE. Determination of gross α and β activity concentration and estimation of adults and infants dose intake in surface and ground water of ten oil fields environment in western Niger Delta of Nigeria. *International Journal of Environmental Engineering Research* 2011; 1(1): 30-40.

Akbulut S, Taskın H. Determination of natural radioactivity by gross α and β measurements in tap waters in Rize province. *Journal of Radioanalytical and Nuclear Chemistry* 2015; 303(1): 413-420.

Cfarku F, Xhixha G, Bylyku E, Zdruli P, Mantovani F, Përpunja F, Thoma, H. (2014). A preliminary study of gross alpha/beta activity concentrations in drinking waters from Albania. *Journal of Radioanalytical and Nuclear Chemistry* 301(2): 435-442. http://doi.org/10.1007/s10967-014-3142-x

Damla N, Çevik UĞUR, Karahan GKAI, Kobya AI. Gross α and β activities in tap waters in Eastern Black Sea region of Turkey. *Chemosphere* 2006; 62(6): 957-960. https://doi.org/10.1016/j.chemosphere.2005.05.051

Eckerman KF, Wolbarst AB, Richardson AC. Limiting values of radionuclide intake and air concentration and dose conversion factors for inhalation, submersion, and ingestion: Federal guidance report No. 11 (No. EPA-520/1-88-020). *Environmental Protection Agency, Washington, DC (USA). Office of Radiation Programs; Oak Ridge National Lab, TN (USA)* 1988.

Fernandez F, Lozano JC, Gomez JMG. Natural radionuclides in ground water in western Spain. *Radiation Protection Dosimetry* 1992; 45(1-4): 227-229. https://doi.org/10.1093/rpd/45.1-4.227

Forte M, Rusconi R, Cazzaniga MT, Sgorbati G. The measurement of radioactivity in Italian drinking waters. *Microchemical Journal* 2007; 85(1): 98-102. https://doi.org/10.1016/j.microc.2006.03.004

Ferdous M, Rahman M, Begum A. Gross alpha and gross beta activities of tap water samples from different locations of Dhaka City. *Sri Lankan Journal of Physics* 2012; 13(1): 1-8.

Gruber V, Maringer FJ, Landstetter C. Radon and other natural radionuclides in drinking water in Austria: measurement and assessment. *Applied radiation and isotopes* 2009; 67(5): 913-917.

Hamzah Z, Saat A, Alias M, Rahman SAA, Kassim M, Ishak AK. Measurement of gross alpha, gross beta, radon and radium activity concentrations in aqueous samples using liquid scintillation technique. *Journal of Nuclear and Related Technologies* 2011; 8(2), 85-93.

International Organization for Standardization (ISO) (1992)Water Quality-Measurement of Gross & Alpha; Activity in Non-Saline Water-Thick Source Method, London.

Miao XX, Ji YQ, Shao XZ, Wang H, Sun QF, Su X. Radioactivity of drinking-water in the vicinity of nuclear power plants in China based on a large-scale monitoring study. *International journal of environmental research and public health* 2013; 10(12): 6863-6872. http://doi.org/10.3390/ijerph10126863

Najib MU, Zakari YI, Sadiq U, Bello IA, Ibrahim GG. Measurement of radioactivity in water of Zobe Dam Dutsinma, Katsina State, Northern Nigeria. *Archives of Applied Science Research* 2014; 6(6): 28-33.

Ogundare FO, Adekoya OI. Gross alpha and beta radioactivity in surface soil and drinkable water around a steel processing facility. *Journal of radiation research and applied sciences* 2015; 8(3): 411-417.

Otton JK. National Radioactivity in the Environment 1994. http://energy.usgs.Gov/factsheets/radioactivity

User's Manual. Model LB-4100 Low Background Counting System, United States of America 2003.

World Health Organization (WHO). *Guidelines for Drinking-Water Quality, 4th ed, Geneva Switzerland* 2011.

World Health Organization (WHO). *Guidelines for drinking-water quality, 3rd edition, Geneva,* 2006; 1: 197–207.

Abbasi A, Mirekhtiary F. Gross alpha and beta exposure assessment due to intake of drinking water in Guilan, Iran. *Journal of Radioanalytical and Nuclear Chemistry* 2017; 314(2): 1075-1081.

Wang Y, Tian K, Wang H, Sang W. An investigation of gross α & gross β radioactivity level of Xiaoqing River from 2008 to 2015. *International Journal of Scientific Reports* 2015; 1(5): 226-227.

Al-Sawaff ZH, Rashid ZM, Yahya YZ, Kandemirli F. Electromagnetic field smart splint for bone fixing and rehabitation using niti shape memory alloy. *NeuroQuantology* 2020; 18(3): 37-44.