Journal of Applied Research in Water and Wastewater

E-ISSN: 2476-6283

Journal homepage: https://arww.razi.ac.ir

Evaluation of natural radioactivity in Tehran's water using the gross alpha and beta measurements

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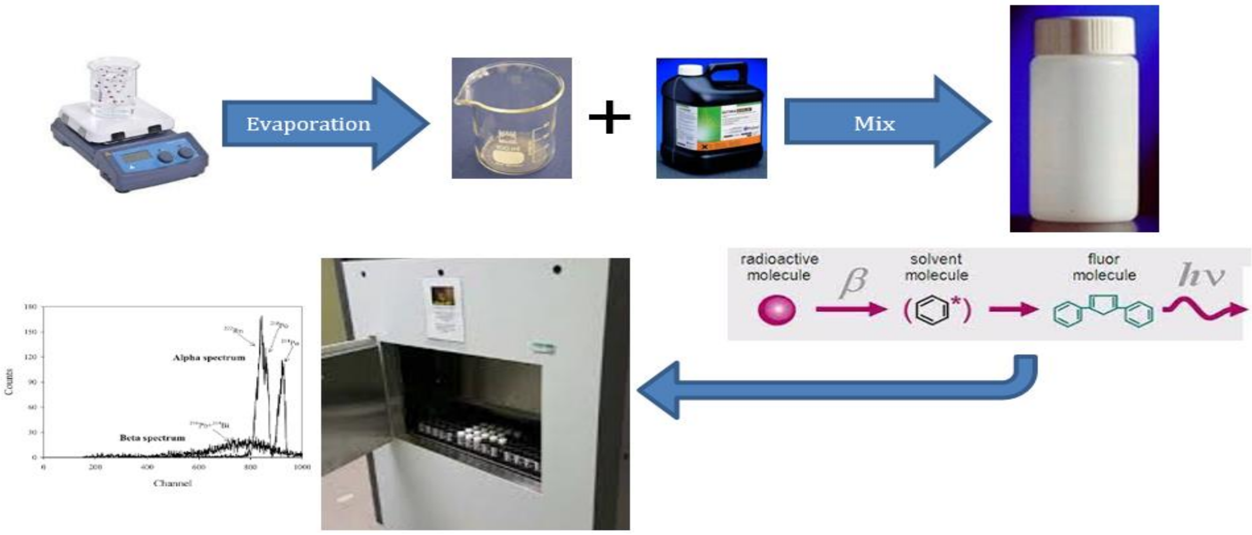
GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 28 August 2021
Reviewed 30 October 2021
Received in revised form 29 November 2021
Accepted 2 December 2021
Available online 4 December 2021

Keywords:
Gross beta
Gross alpha
Natural radioactivity
Liquid scintillation counting

Article type: Research Article

ABSTRACT

Consumption and drinking of healthy and high-quality water is considered an important matter in human life, so monitoring of drinking water pollution including radioactive contamination and assessing the amount of radiation exposure of people through water consumption is very important. The purpose of this investigation was to measure the concentration of gross beta and alpha activities in water samples collected from Tehran water sources. In the present study, the gross beta and alpha activity concentrations of 35 water samples in Tehran were analyzed and measured to evaluate their radiological quality using liquid scintillation method. The results of the analysis showed the activity concentration of gross alpha ranges from 48 mBq/L to 227 mBq/L with a mean of 137.5 mBq/L. the activity concentration of gross beta in the samples ranged from 49 mBq/L to 328 mBq/L with a mean of 184.7 mBq/L. Also, the correlation coefficient between the results were very strong and equal to 0.87. The results showed that the gross beta and alpha activity concentrations in all waters was lower than the standard limit of the World Health Organization (WHO) and the Institute of Standards and Industrial Research of Iran, which is 500 mBq/L and 1000 mBq/L, respectively and also waters are radiologically healthy.

1. Introduction

The most important factor for human survival after oxygen is water and more than 70% of body weight is water. Water, directly and indirectly, affects the health and activities of all organs of the body at all ages and if contaminated water is consumed, problems and disease are inevitable. Drinking healthy and high-quality water is considered an important issue in human life. Therefore, human attention to the health of drinking water has increased from ancient times to the present day because most of the water needed by the body is provided through drinking water (WHO 2011). Today, with the growth and expansion of industries as well as industrial accidents in developing and developed countries, water pollution has increased. Investigation and monitoring of drinking water pollution is an important parameter for public health and environmental health studies and it is necessary to study it from different aspects. One of the most important aspects is to study the presence of various radionuclides in the water that emit alpha, beta and gamma rays when their nuclei decay. The radioactivity in water is mainly due to the radioactive elements that are naturally present in the earth's crust. In addition, synthetic radionuclides are also contaminate water with radioactive materials because of some human activities such as Nuclear facilities, use of nuclear weapons, the production and consumption of radioactive drugs, and events such as those that occurred in Japan (Turhan et al. 2013).

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How to cite: H. Ranjbar, M. Tabasi, Evaluation of natural radioactivity in Tehran's water using the gross alpha and beta measurements, *Journal of Applied Research in Water and Wastewater*, 8 (2), 2021, 129-132.

In addition to harming health, radioactive materials also increase the risk of some cancers, even if small amounts of radioactive elements are ingested or inhaled. One of the main ways in which radioactive materials penetrate the human body is to drink water contaminated with natural and man-made radioactive sources. Due to the dangerousness of water contamination with radioactive materials, it is important to monitor the radioactivity of water and determine the concentrations of radionuclides in drinking water (Labidi et al. 2010). Governments and international organizations at all levels to protect and safeguard public health have developed guidelines and standards for assessing water quality, given the high degree of human vulnerability to contaminated water consumption. Of course, different countries set their water quality standards according to their national requirements and priorities and according to the recommended limits of international standards.

In Iran, radiological criteria for drinking water quality are determined by the Iranian Institute of Standards and Industrial Research. According to the recommendations of the National Standard of Iran (ISIRI, 2010), specific radionuclide analysis (i.e. separate measurement of the radionuclides concentrations individually) is required for drinking water samples only when the gross beta and alpha activity are greater than 1000 and 500 mBq/L respectively. Measurement of gross beta and alpha concentrations mean the measurement of all radionuclides in water with each other. If the gross beta and alpha radioactivity concentrations in a water sample do not exceed any of the above values, it is no longer necessary to specifically identify and determine the activity of other radionuclides. Tehran is the most populous city in Iran, which has special conditions due to the focus of various economic, educational, cultural, political activities and the existence of large factories and workshops around it. So that a large number of people from the surrounding cities enter this city every day for various reasons and along with the population of Tehran themselves need to provide safe water and free from any pollution, including radioactive pollution. Therefore, one of the important issues of organizations and health authorities is the supply of safe water.

So far, many studies have been performed on the amount of radioactivity concentrations in various water samples in some regions of Iran and other countries (Abbasi 2017; Hosseini 2014; Mehdizadeh 2013; Mingote 2019; Parhoudeh 2019; Turhan 2020). However, comprehensive information about the radioactivity of drinking water sources in Tehran using liquid scintillation method has not been reported in scientific articles and texts. Therefore, the purpose of this research was to measure the gross beta and alpha activity concentrations in water samples collected from Tehran water sources to ensure that Tehran's drinking water is free of radioactive contamination and its use has no radiological risk.

2. Materials and Methods

2.1. Sample collection

To evaluation of natural radioactivity in Tehran's water, 35 groundwater were selected from different wells in Tehran (TDW), which are coded in Table 1. Samples were stored in 2-liter bottles for laboratory delivery. The pH of the solution was adjusted to about 2-3 using 60 % nitric acid to prevent radionuclide deposition and colloid formation, as well as to inhibit the biological activity of microorganisms.

2.2. Sample preparation

The standard method of ISO 11704 (ISO 2010) is used to measure gross beta and alpha radioactivity concentrations in water samples. According to this standard, to increase the accuracy of the measurement of radioactivity in water, 250 ml of water is poured into a beaker placed on a hot plate stirrer and concentrated by gentle evaporation to the drying stage. The residual material in the beaker is then washed with 10 mL of double distilled water and transferred to a special 20 mL vial of liquid scintillation counter (LSC) and 10 mL of Ultima Gold (Perkinelmer 2021) is added to it.

2.3. Sample counting by LSC

One of the most accurate and best methods for counting alpha and beta emitting radionuclides in water samples is the liquid scintillation counter. The advantages of using a liquid scintillation counter are as follows: Simultaneous measurement of alpha and beta emitting radionuclides in the sample, excellent efficiency of nearly 100% for the high-energy alpha and beta emitter, and the measurement of radioactivity of samples with very low activity concentration. In this study, to measure the amount of water activity concentration, the samples prepared according to the method mentioned in the previous section are counted with a liquid scintillation counter model 1220 Quantulus for 240 minutes. The count of each sample is repeated twice and the average of the counts is used to measure the radioactivity concentrations.

2.4. Measurement of the radioactivity concentration in water

The radioactivity concentrations of water with a given volume V is determined by following equation (L'Annunziata. 2012)

$$A_{\alpha/\beta} = \frac{N_{net}}{\varepsilon \times V \times 60} \tag{1}$$

where, A is the gross alpha or beta activity concentration in Bq/l, N is the true count rate, ε is the efficiency of detection, V is the volume of sample in L, and 60 is the conversion factor for changing from decay per minute (dpm) to decay per second (dps).

3. Results and discussion

An important point in measuring very low radioactivity is the Minimum Detectable Activity (MDA). In other words, the most important indicator of the accuracy of a method is its detection limit. The minimum detectable activity for gross beta and alpha are obtained from Equation 2 (Currie. 1968).

$$MDA = \frac{2.71 + 4.65\sqrt{N_B \times T}}{\varepsilon \times V \times T \times 60} \tag{2}$$

MDA for gross beta and alpha was obtained 0.035 Bq/L and 0.025 Bq/L.

Table 1. The radioactivity concentrations of gross beta and alpha in the water samples.

Sampling code	Gross alpha, mBq/L	Gross beta, mBq/L
TDW 1	81	137
TDW 2	139	173
TDW 3	92	142
TDW 4	52	73
TDW 5	177	312
TDW 6	63	86
TDW 7	101	116
TDW 8	122	198
TDW 9	148	151
TDW 10	48	49
TDW 11	117	92
TDW 12	134	285
TDW 13	57	61
TDW 14	153	187
TDW 15	169	173
TDW 16	191	229
TDW 17	172	293
TDW 18	196	266
TDW 19	49	49
TDW 20	63	68
TDW 21	188	214
TDW 22	153	262
TDW 23	163	192
TDW 24	174	225
TDW 25	211	328
TDW 26	125	184
TDW 27	145	164
TDW 28	165	241
TDW 29	108	203
TDW 30	165	221
TDW 31	129	158
TDW 32	227	297
TDW 33	158	179
TDW 34	180	209
TDW 35	196	247

The gross beta and alpha activity concentrations analyzed in the waters are shown in Table 1. As the results show the measured gross alpha radioactivity concentrations in water samples varies from 29 to 49 mBq/L with amean of 38.7 mBq/L. The gross beta radioactivity concentrations in water samples were measured from 48 to 76 mBq/L with a mean of 184.69 mBq/L. The reason for the difference in concentrations measured in the samples is that the natural radioactivity in the water appertains on the geological characteristics of the harvest site. These radioactive substances in water are mainly occurred from radionuclides of the natural decay chains of uranium-238, thorium-232 and potassium-40 present in the environment. Some natural radioactive materials are easily soluble in water due to the reaction of groundwater with soil and bedrock, which depends on the chemical properties of bedrock and soil, oxidation conditions and retention time of groundwater below the land and the cracks in the bedrock and soil. As a result, the amount of water-soluble radionuclides and, by nature, the activity concentrations in water samples differ, although these differences are small. In a study, Bayat et al studied gross beta and alpha activities in Tehran waters with proportional counter and alpha-spectrometry (Bayat et al. 2015). Like our results, their research showed that alpha and beta activities are within the allowable range. There are various problems and interfering factors such as self-absorption and the need for a tracer in measuring gross beta and alpha by proportional counter and alpha spectrometry. But the LSC method is a more accurate and convenient way to measure gross beta and alpha.

Basic descriptive statistics such as minimum, maximum, mean, standard deviation, skewness and kurtosis for gross beta and alpha radioactivity concentrations in the water are shown in Table 2.

Table 2. Statistical data for gross beta and alpha activity measured in the 35 water samples.

Parameter	Gross beta, mBq/L	Gross alpha, mBq/L
Mean	184.69	137.46
Maximum	328	227
Minimum	49	48
Standard deviation	77.78	49.96
Standard error	13.15	8.45
Skewness	-0.12	-0.40
Kurtosis	-0.74	-0.79

In statistic science, skewness is a criterion of the symmetry or asymmetry of a distribution function. For a perfectly symmetric distribution the skewness is zero, for an asymmetric distribution with the tail on the right side of the distribution the skewness is positive, and for an asymmetric distribution with the tail on the left side of the distribution the skewness is negative. The results of this study and the negative skewness of the data show that the number of water samples whose radioactivity is higher than the average value, are more than the number of samples whose radioactivity is lower than the average. Fig. 1 shows the relationship between gross beta and alpha activity concentrations in water samples. As can be seen from the figure, the correlation between these two parameters is strong and significant (correlation coefficient = 0.87). Correlation coefficient is one of the criteria used to determine the dependence between two variables. The correlation coefficient indicates the intensity of the relationship as well as the type of relationship (direct or inverse) in the sense that the change in one variable is consistent with the change in the other variable. The high correlation coefficient between the results of gross alpha concentration and gross beta concentration means that the prediction of the gross beta concentration from the gross alpha concentration for other water samples is valid and accurate. According to the guidelines of the National Standard of Iran to control radiological hazards in water, the following two-step method should be performed. Initial screening is done to measure gross beta and alpha concentrations to determine if the radionuclides concentrations are below the allowable level. Then if the activity concentrations is higher than the allowable level, the concentrations of radionuclides should be checked individually. These suggestions are shown in Tables 3 and 4, which are exactly in the document of the Institute of Standards and Industrial Research of Iran.

Table 3. Screening levels for radioactivity concentrations in drinking water (ISIRI 2010).

	initial screening	Screening levels	Unit
1	Gross Alpha	0.5	Bq per Liter
2	Gross Beta	1	Bq per Liter

The results show that gross beta radioactivity concentrations in the samples is higher than the gross alpha activity concentrations in the samples. In addition, gross alpha concentration is less than the maximum screening level of 500 mBq/L and also gross beta concentrations are less than the recommended value for beta of 1000 mBq/L.

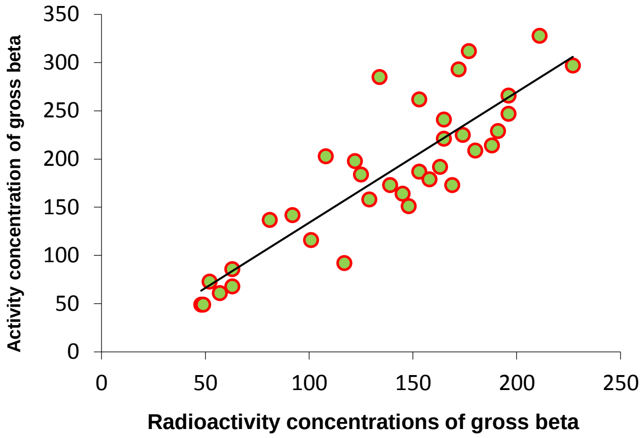

Fig. 1. The strong correlation between gross beta and alpha activity concentrations (mBq/L).

Table 4. Guidance levels for radionuclides in drinking water (ISIRI 2010).

	Radionuclides	Guidance levels	Unit
1	Radium-226	1	Bq/L
2	Radon	100	Bq/L
3	Uranium	0.015	Mg/L

4. Conclusions

Detection and investigation of radioactive materials in water samples are an important indicator for public health studies because in this way the amount of radiation exposure of people in the community from water consumption can be achieved. Because of the internal exposure due to the decay of radionuclides absorbed in the body through ingestion, the presence of radioactive materials in drinking water endangers public health. Published scientific texts and articles show that this is the first study on measuring the amount of radioactivity in the drinking water of the capital of Iran as the largest and most populous metropolis in the country by liquid scintillation method. Measurement of gross beta and alpha activity concentrations by screening method is used as the first step in determining radioactivity in water samples. This is because of the simplicity of the technique, as measuring gross alpha and beta radioactivity provides a cost-effective general method over a relatively short period of time. In this study, 35 water samples from different water sources in Tehran were studied and radioactivity was measured. The reason for this study is that the amount of natural radioactivity in the waters may be high. This is because the radionuclides of the uranium and thorium decay series present in the soil and bedrock can dissolve in the groundwater in contact with them. Fortunately, the results of the analysis of all samples showed that all the tested sources comply with the permissible limits stated in the guidelines of the National Standard of Iran and are safe and suitable for consumption in term of radiological quality.

Acknowledgment

We are thankful to our colleagues in the Nuclear Analysis Laboratory who provided expertise that greatly assisted the research.

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