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Tritium activity levels in drinking water of Adana, Turkey

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Abstract Tritium activity in potable drinking water samples from Adana city were measured using liquid scintillation counting after distillation procedure. The results exposed that the activity concentrations of the tritium measured in one-third of these samples were lower than minimum detectable activity which has a value of 2 Bq/L for counting time of 1,500 min. However, the maximum and mean value of the tritium activity was found to be 9.1 Bq/L (77.3 TU) and 7.0 Bq/l (59.4 TU), respectively. These values were substantially below the 100 Bq/L which is normative limit in Turkey for waters intended for human consumption. The highest values of annual effective dose received by infants, children and adults due to measured tritium activity were estimated as 0.041, 0.057 and 0.120 μSv/y, respectively.

Keywords Tritium · Liquid scintillation counting · Drinking water · Annual effective dose · Adana (Turkey)

Introduction

Tritium (^{3}H, $t_{1/2} = 12.3\ a$) radioactive isotope of hydrogen decays as a beta emitter. Tritium is produced naturally in the upper atmosphere when cosmic ray interacts with nitrogen and oxygen nuclei [1]. Tritium was also produced artificially during nuclear weapon tests conducted from 1945 until 1963 and production of electricity by nuclear reactors. However, the concentration of tritium in the atmosphere reached the maximum level in 1963, which has been decreasing at a rate equal to its half-life [2].

Tritium exhibits almost the same physical and chemical properties of hydrogen and so it reacts with oxygen to form radioactive water (tritiated water, HTO) molecules. HTO enter into hydrologic cycle in the environment like ordinary water. Tritium entering the human body by ingestion, inhalation, and through the skin by absorption, diffuses freely and rapidly across the membrane of soft tissue [3]. Hence, it is important to determine the levels of tritium activity in water samples intended for human consumption. Tritium concentration limit in drinking water established by European Directive [4] and Turkish drinking water legislation [5] is 100 Bq/L. Nowadays, many studies related to determination of the tritium activity levels in water samples from different origins were carried out in various countries [6–12]. There are few studies on the measurement of tritium activity concentration in drinking water in Turkey [13, 14]. However, data on tritium activity in drinking water consumed in Adana city is not available in the literature. Adana city is the Turkey's fifth largest city (a population of 2,125,635). Adana city lies in the heart of Çukurova region which is a geographical, economic and cultural region and covers the provinces of Mersin, Adana, Osmaniye, and Hatay. There is no nuclear power plant in Adana city. But, Adana is about 140 km to Akkuyu nuclear power plant having installed total power of 4,800 will be built in Turkey, at Mersin province on the Mediterranean coast.

In the present study, the activity concentrations of the tritium in drinking water samples consumed in Adana city

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was measured using a liquid scintillation counter (LSC) system, which is the most commonly used technique for measuring radionuclides emitting low-energy beta activity, such as tritium, after distillation and enrichment process.

Experimental

Sample and sample preparation

Twenty-one drinking water samples were collected from the different tap water systems (public water supply systems) in Adana city (Fig. 1). In Adana city, surface water supplied from Çatalan Dam constructed on the Seyhan River is used as drinking water. The water samples were transported in 1 L well-sealed plastic bottles to laboratory for the tritium measurement. Conductivity of all samples was measured before distillation procedure which was performed to avoid any impurities, reduce quenching and prevent the introduction of other radionuclides altering measurement results [9]. All reagents such as sodium hydroxide (NaOH), potassium permanganate ($KMnO_4$) and liquid scintillation cocktail in experimental procedures were of analytical grade. Each water samples was placed in a distillation volumetric flask of 250 mL. Then, a few drops of 0.05 N of $KMnO_4$ and 6 M of NaOH were added

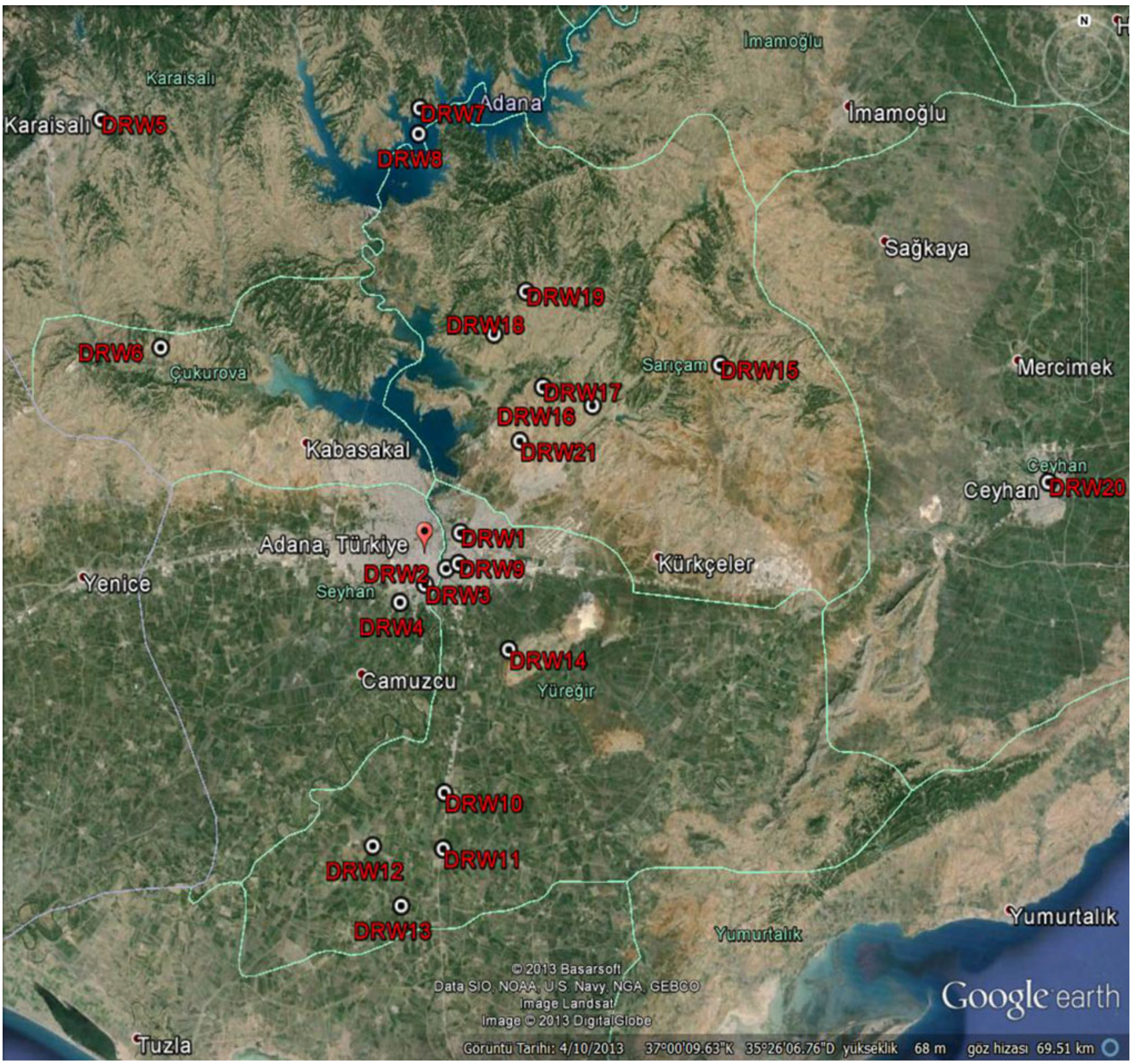

Fig. 1 The location of sampling sites in Adana province

and the distillation process was accomplished at a temperature range of 100–105 °C.

Sample counting

An aliquot of 8 mL of the distillate was placed in a 20 mL polyethylene scintillation vial, and mixed with 12 mL of scintillation cocktail (Ultima Gold LLT, Packard). The prepared samples were stored in dark room for 24 h to eliminate the quenching and the effect of luminescence in the vial before LSC measurements. Then, the samples of dead water (DW), laboratory standard (LS), and spike standard (SS) and drinking water (DRW) in vials were counted for three cycles of 500 min each. The total measurement time for each sample was approximately 1,500 min. Beta counting was performed using the Packard TriCarb 2900TR which is a computer-controlled benchtop liquid scintillation analyzer. Tritium spectrum was calibrated by using a calibration protocol called Self-Calibration and Normalization/Instrument Performance Assessment, measuring a set of ^{3}H standards (2434.6 Bq/L on 11 January 2011).

Measurement of the tritium activity in the drinking water samples

The minimum detectable activity (MDA) used to discriminate a measurement from the background was calculated using equation below [9, 15]:

$$\mathrm{MDA(Bq/L)} = \frac{16.7 + 3.29\sqrt{\mathrm{cpm}_{\mathrm{DW}} \cdot t_{\mathrm{SS}} \cdot \left(1 + \frac{t_{\mathrm{SS}}}{t_{\mathrm{DW}}}\right) + 3}}{\varepsilon \cdot t_{\mathrm{DW}} \cdot V} \tag{1}$$

where $\mathrm{cpm}_{\mathrm{DW}}$ is the net count rate of the dead water sample (counts per minute); t_{SS} and t_{DW} are the spike standard and the dead water sample counting time (1,500 min), respectively; V is the volume of the sample (L); ε is the counting efficiency. Tritium activity concentration in the drinking water sample is obtained by the following equation:

$$A(\mathrm{Bq/L}) = \frac{\mathrm{cpm}_{\mathrm{DRW}} - \mathrm{cpm}_{\mathrm{DW}}}{60 \cdot \varepsilon \cdot V \cdot F} \tag{2}$$

where $\mathrm{cpm}_{\mathrm{DRW}}$ and $\mathrm{cpm}_{\mathrm{DW}}$ are the net count rate of the drinking water and the dead water sample (counts per minute) and F is chemical yield. The tritium activity concentrations were converted to tritium unit (TU) using the following relation:

$$A(\mathrm{TU}) = \frac{\mathrm{A\ (Bq/L)}}{0.118}. \tag{3}$$

Results and discussion

The minimum detectable activity was calculated as 2 Bq/L for counting time of 1,500 min using Eq. (1). The activity concentrations of the tritium (in terms of Bq/L and TU) measured in 21 drinking water samples collected from Adana are presented in Table 1. The activity concentrations of the tritium varied from <MDA to 9.1 Bq/L (77.3 TU) with a mean of 7.0 ± 0.2 Bq/L (59.4 ± 1.6 TU). Table 2 presents the tritium activity concentrations in water samples from different origin. The mean activity concentration of the tritium measured in the present study is comparable with those reported in the literature.

Annual effective dose (E_{eff}) associated with radiation exposure through ingestion of the drinking water sample was estimated to assess the health risk to the members of the public (infants, children and adults) using the following formula:

Table 1 The values of the tritium activity concentration measured in the drinking water samples

Sample code	Activity concentration of tritium	
	(Bq/L)	TU
DRW1	<2[a]	<16.9[b]
DRW2	<2	<16.9
DRW3	<2	<16.9
DRW4	<2	<16.9
DRW5	<2	<16.9
DRW6	<2	<16.9
DRW7	<2	<16.9
DRW8	9.1 ± 1.8	77.3 ± 15.3
DRW9	7.9 ± 1.8	67.1 ± 15.3
DRW10	7.7 ± 1.4	64.8 ± 11.9
DRW11	8.3 ± 1.8	70.1 ± 15.3
DRW12	6.8 ± 1.9	57.4 ± 16.1
DRW13	5.3 ± 1.7	44.9 ± 14.4
DRW14	4.7 ± 1.8	39.9 ± 15.3
DRW15	7.4 ± 1.8	62.3 ± 15.3
DRW16	6.5 ± 1.6	54.9 ± 13.6
DRW17	8.4 ± 1.4	71.4 ± 11.9
DRW18	9.0 ± 1.4	76.5 ± 11.9
DRW19	6.3 ± 1.8	53.5 ± 15.3
DRW20	4.5 ± 1.5	38.2 ± 12.7
DRW21	6.3 ± 1.4	53.5 ± 11.9
Mean ± SD	7.0 ± 0.2	59.4 ± 1.6
Min.	<2	<16.9
Max.	9.1	77.3

[a] MDA is 2 Bq/L

[b] MDA is 16.9 TU

$$E_{eff}(\mu Sv/y) = A\ (Bq/L) \times D_C\ (Sv/Bq) \times I_W\ (L/y) \times 10^6 \quad (4)$$

where A is the activity concentration of the tritium; D_C is the dose coefficient (1.8×10^{-11} Sv/Bq for tritium) and I_W is the intake of drinking water volume for the members of the public [18]. Annual effective dose was estimated for infants, children and adults assuming that the water intake volume per year for infants, children and adults is 250, 350 and 730 L, respectively [18]. The estimated E_{eff} values for the water samples are given in Table 3. The values of E_{eff} estimated for infants, children and adults ranged from 0.009 to 0.041 μSv/y, 0.013 to 0.057 μSv/y and 0.026 to 0.120 μSv/y, respectively.

Table 2 Tritium activity concentrations comparison with the literature

Origin	Tritium activity concentration (Bq/L)	Reference
Italy (drinking water)	<10	[16]
Greece (surface water)	0.9	[17]
Spain (surface water)	3.6	[9]
Portugal (surface water)	1–20[a]	[2]
Turkey (Adana)	7	This study

[a] Range (min–max)

Table 3 The annual effective dose estimated for the members of the public (infants, children and adults)

Sample code	Annual effective doses (μSv/y)		
	Infant	Children	Adults
DRW1	0.009[a]	0.013[a]	0.026[a]
DRW2	0.009[a]	0.013[a]	0.026[a]
DRW3	0.009[a]	0.013[a]	0.026[a]
DRW4	0.009[a]	0.013[a]	0.026[a]
DRW5	0.009[a]	0.013[a]	0.026[a]
DRW6	0.009[a]	0.013[a]	0.026[a]
DRW7	0.009[a]	0.013[a]	0.026[a]
DRW8	0.041	0.057	0.120
DRW9	0.036	0.050	0.104
DRW10	0.034	0.048	0.101
DRW11	0.037	0.052	0.109
DRW12	0.030	0.043	0.089
DRW13	0.024	0.033	0.070
DRW14	0.021	0.030	0.062
DRW15	0.033	0.046	0.097
DRW16	0.029	0.041	0.085
DRW17	0.038	0.053	0.111
DRW18	0.041	0.057	0.119
DRW19	0.028	0.040	0.083
DRW20	0.020	0.028	0.059
DRW21	0.028	0.040	0.083
Mean ± SD	0.024 ± 0.012	0.034 ± 0.017	0.070 ± 0.036
Min.	0.009	0.013	0.026
Max.	0.041	0.057	0.120

[a] MDA was taken as 2 Bq/L

Conclusion

The tritium activity levels in drinking water samples collected from the 21 different public water supply systems in Adana city were determined to check the compliance with national regulation. It can be easily seen from evident that the tritium activities in all the samples were much lower than upper limit value of 100 Bq/L recommended by Turkish drinking water legislation (Official Journal No. 25730, February 2005) and Turkish standards [19]. Also, the values of annual effective dose estimated for the members of public were significantly below the individual dose criterion of 100 μSv/y recommended by Turkish drinking water legislation.

Consequently, the measurements of tritium indicate that the drinking water samples consumed in Adana city are devoid of health risks from tritium.

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References

1. UNSCEAR (2008) Sources and effects of ionizing radiation. United Nations Scientific Committee on the Effects of Atomic Radiation, United Nations Publication, New York
2. Madruga MJ, Sequeira MM, Gomes AR (2009) Determination of tritium in waters by liquid scintillation counting. LSC 2008, advances in liquid scintillation spectrometry by the Arizona Board of Regents on behalf of the University of Arizona, pp 353–359
3. Kim HG, Kong TY, Jeong WT, Kim ST (2011) Progress Nucl Sci Technol 1:529–532
4. Council Directive 98/83/EC of November 3 on the quality of water intended for human consumption. Official Journal of the European Communities, L330/32-330/54
5. Official Journal 25730 (2005) İnsani Tüketim Amaçlı Sular Hakkında Yönetmelik, 17 January 2005 (in Turkish)
6. Moraes MAPV, Sartoratto M, Sartoratto BEL, Oliveira CB, Mendes VA (2002) Radiat Meas 35:333–337
7. Villa M, Manjón G (2004) Appl Radiat Isotopes 61:319–323
8. Karamanis D, Stamoulis K, Ioannides KG (2007) Desalination 213:90–97
9. Palomo M, Peñalver A, Aguilar C, Borrull F (2007) Appl Radiat Isotopes 65:1048–1056

10. Desideri D, Roselli C, Feduzi L, Meli MA (2007) Microchem J 87(1):13–19
11. Onugba A, Aboh HO (2009) Nigeria Sci World J 4(2):23–28
12. Hatano Y, Hara M, Ohuchi-Yoshida H, Nakamura H, Yamanishi T (2012) Fusion Eng Des 87:965–968
13. Top G (2008) Tritium measurements in drinking water in Eskisehir. International Physics Congress of the Turkish Physical Society, Bodrum. Abstracts, 764, pp 243
14. Görür FK, Genç E (2012) Desalin Water Treat 44:215–222
15. Currie LA (1968) Anal Chem 40:586–593
16. Forte M, Rusconi R, Cazzaniga MT, Sgorbati G (2007) Microchem J 85:98–102
17. Stamoulis KC, Karamanis D, Ioannides KG (2011) Fusion Eng Des 86:206–213
18. WHO (2011) Guidelines for Drinking-water Quality, 4th edition, WHO Library Cataloguing-in-Publication Data NLM classification: WA 675, Geneva
19. TS 266 (2005) Water intended for human consumption, ICS 1.060.20, Ankara