Chemosphere 112 (2014) 134–140

Contents lists available at ScienceDirect

Chemosphere

journal homepage: www.elsevier.com/locate/chemosphere

Natural radioactivity in various water samples and radiation dose estimations in Bolu province, Turkey

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HIGHLIGHTS

- This study was determined the gross α–β activity in various waters.
- The associated age-dependent dose from all water ingestion in Bolu was estimated.
- The total dose for adults had an average value exceeds the WHO recommended limit value.
- The lifetime risk from tap and mineral waters was determined.

ARTICLE INFO

Article history:
Received 17 December 2013
Received in revised form 27 January 2014
Accepted 22 February 2014

Handling Editor: S. Jobling

Keywords:
Gross α
Gross β
Water
Effective dose equivalent
Lifetime risk
Bolu

ABSTRACT

The level of natural radioactivity for Bolu province of north-western Turkey was assessed in this study. There is no information about radioactivity measurement reported in water samples in the Bolu province so far. For this reason, gross α and β activities of 55 different water samples collected from tap, spring, mineral, river and lake waters in Bolu were determined. The mean activity concentrations were 68.11 mBq L^{-1}, 169.44 mBq L^{-1} for gross α and β in tap water. For all samples the gross β activity is always higher than the gross α activity. All value of the gross α were lower than the limit value of 500 mBq L^{-1} while two spring and one mineral water samples were found to have gross β activity concentrations of greater than 1000 mBq L^{-1}. The associated age-dependent dose from all water ingestion in Bolu was estimated. The total dose for adults had an average value exceeds the WHO recommended limit value. The risk levels from the direct ingestion of the natural radionuclides in tap and mineral water in Bolu were determinated. The mean ^{210}Po and ^{228}Ra risk the value of tap and mineral waters slightly exceeds what some consider on acceptable risk of 10^{-4} or less.

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1. Introduction

The water has an importance in environmental studies because of its daily use for human consumption and its ability to transport pollutants. Radionuclides in drinking water causes human internal exposure, caused by the decay of radionuclides taken into the body through ingestion and inhalation indirectly when they are incorporated as part of the human food chain. Measurements of natural radioactivity in drinking water have been performed in many parts of the world, mostly for assessment of the doses and risk resulting from consuming water (Degerliler and Karahan, 2010).

Drinking water is the most important food for human beings. Access to safe drinking water is essential to health, a basic human right and a component of effective policy for health protection (WHO, 2011). For this reason its quality must be strictly controlled. Drinking water may contain radioactivity that could present a risk to human health. The radioactivity in ground water comes mainly from radionuclides of the natural decay chains ^{238}U and ^{232}Th, and ^{40}K in soil and bedrock. Some radionuclides can dissolve easily in water, depending on the mineralogical and geochemical composition of the soil and rock, redox conditions and the residence time of ground water in the soil and bedrock, as result of the reaction of the ground water with soil and bedrock (Verterbacka, 2007). Consequently these radionuclides transported in ground water can enter the food chain through irrigation waters and the water source through ground water wells. Thus the ingestion of radionuclides in drinking water causes human internal exposure.

Environmental radiation originates from a number of naturally occurring and man-made sources. The largest proportion of human exposure to radiation comes from natural sources of external radiation, including cosmic and terrestrial radiation and from

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http://dx.doi.org/10.1016/j.chemosphere.2014.02.074
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inhalation or ingestion of natural radioactive materials. The United Nations Scientific Committee on the Effects of Atomic Radiation has estimated that exposure to natural sources contributes >70% of the population radiation dose and the global average human exposure from natural sources is 2.4 mSv y^{-1} (cosmic ray 0.4, terrestrial gamma ray 0.5, radon 1.2, and food and drinking water 0.3) (UNSCEAR, 2000).

Gross alpha and beta activities are very useful parameters for the preliminary screening of waters. For practical purposes, the recommended guideline activity concentrations are 500 mBq L^{-1} for gross α activity and 1000 mBq L^{-1} for gross β activity for drinking water (WHO, 2011). The main α emitting radionuclides in the natural decay series are ^{238}U, ^{234}U, ^{230}Th, ^{226}Ra, ^{210}Po, ^{232}Th and ^{228}Th. The major β emitting radionuclides are ^{210}Pb and ^{228}Ra as well as ^{40}K (Bonotto et al., 2009).

Hitherto, many studies were performed on radioactivity in various water samples (tap water, surface water, thermal spring water, river water) collected from some cities in Turkey and other countries (Malanca et al., 1998; Degerliler and Karahan, 2010; Görür et al., 2011; Kobya et al., 2011; Taskin et al., 2012; Al-Amir et al., 2012). However systematic data on the radioactivity of public water supplies in Bolu province is not available in the literature.

The province of Bolu is situated in the north-western part of Turkey between the latitudes of 40° 06′ and 41° 01′ N and the longitudes of 30° 32′ and 32°36′ E. It has an area of 8276 km^2, nearly 1.02% of the Turkey's total geographical area. Agricultural, forest, and meadows and pastures areas of the province are approximately 18%, 59%, and 15%, respectively. An estimation of the activity concentrations of radioactivity in different water supplies in Bolu is extremely important for proper assessment of the hazards associated with their intake. Turkey did not have guidelines for gross alpha and beta activity concentrations in drinking water until the first guidelines were put into effect by the Institute of Turkish Standards in 1997. The main aim of this study is to determine the level of radioactivity in different drinking water supplies and in other surface waters in Bolu region.

2. Experimental procedure

2.1. Sample collection and experimental setup

In order to measure the gross α and β activities in waters, various water samples were collected from 55 different sampling stations in Bolu. Sampling sites are listed in Table 1 and shown in Fig. 1. All the water samples were collected in 2 L linear polypropylene bottles which had been carefully washed in the laboratory before the sampling. The bottles were cleaned using a modified procedure (Laxen and Harrison, 1981). The collected water samples were acidified with concentrated nitric acid to pH 2 to avoid the collection of organic materials and changes in the state of the ions present in the samples. The device, used to count the α and β activities, was an α/β counter of the low background multiple detector type (Berthold LB770). The sample detectors are gas flow window-type counters which are approximately 5 cm in diameter. The counting gas was a mixture of 90% argon and 10% methane. All samples were placed in a 5 cm diameter stainless-steel planchet for counting. Lead shielding was used to attenuate external radiation. The operating voltage on the detector was selected to be 1650 V. For each sample there are two separate measuring channels for alpha and beta activities. Background and efficiency data for the detector were collected, stored and used for corrections. The background of the detector was determined by counting an empty planchet for 100 min. The system was calibrated for α and β energies by preparing standard samples which contain equal concentrations. ^{241}Am (913 Bq) and ^{90}Sr (931 Bq) were used to calibrate the system for α and β energies, respectively.

Table 1
The values of the activity concentration of gross α and β measured in the all water samples examined.

Water types	Samples location	Users	pH	Temperature °C	Sampling code	Gross α (mBq L^{-1})	Gross β (mBq L^{-1})
Tap	Bolu	160,500	7.92	19.7	TW1	33 ± 10	155 ± 18
	Mengen	14,623	7.80	17.6	TW2	30 ± 10	50 ± 20
	Göynük	16,123	7.62	17.8	TW3	30 ± 10	50 ± 10
	Mudurnu	20,729	7.25	18.7	TW4	80 ± 30	320 ± 30
	Seben	6106	7.88	18.9	TW5	100 ± 20	140 ± 20
	Kıbrısçık	3611	7.57	18.5	TW6	70 ± 10	200 ± 20
	Gerede	34,679	7.83	16.3	TW7	130 ± 20	270 ± 20
	Yeniçağa	7940	7.81	17.5	TW8	30 ± 10	60 ± 10
	Dörtdivan	6897	7.36	19.2	TW9	110 ± 20	280 ± 20
Lake	Nazlı		8.39	17.7	L1	30 ± 8	250 ± 20
	Büyük		8.76	17.2	L2	20 ± 5	50 ± 10
	Derin		8.16	19.4	L3	22 ± 8	50 ± 10
	İnce		7.68	14.8	L4	25 ± 10	60 ± 10
	Sazlı		7.49	14.4	L5	23 ± 8	50 ± 20
	Serin		8.65	17.5	L6	20 ± 7	40 ± 10
	Şirinyazı		8.33	18.9	L7	20 ± 10	40 ± 10
	Karamurat		8.29	19.4	L8	30 ± 10	110 ± 20
	Sülüklü		8.56	19.3	L9	30 ± 10	50 ± 20
	Çubuk		8.37	21.0	L10	29 ± 9	50 ± 10
	Çayköy		8.70	21.5	L11	40 ± 10	70 ± 10
	Sünnet		8.35	18.0	L12	30 ± 10	90 ± 20
	Amcabey		7.56	17.4	L13	60 ± 10	210 ± 20
	Gölcük		8.24	17.2	L14	120 ± 20	280 ± 20
	Taşlıyayla		7.45	17.3	L15	90 ± 10	160 ± 30
	Karagöl		7.81	17.9	L16	70 ± 10	160 ± 10
	Aladağ		8.84	18.6	L17	70 ± 10	200 ± 10
	Saraycık		7.61	15.7	L18	60 ± 10	230 ± 20
	Gerede		7.84	17.1	L19	60 ± 10	430 ± 60
	Yeniçağa		8.43	18.6	L20	50 ± 20	220 ± 20
	Gölköy		8.48	16.3	L21	30 ± 10	110 ± 10
	Kızılağıl		9.66	16.2	L22	30 ± 10	60 ± 20
	Abant		8.26	15.8	L23	30 ± 10	60 ± 10
	Küçük		9.82	15.1	L24	23 ± 8	61 ± 13
	Sultanbey		7.30	14.2	L25	20 ± 6	100 ± 12
Spring	Karacasu		6.23	34.3	SW1	37 ± 22	802 ± 63
	Sarot		8.92	58.0	SW2	30 ± 10	40 ± 10
	Çatak		7.20	34.9	SW3	110 ± 50	300 ± 20
	Babas		6.65	36.9	SW4	140 ± 50	460 ± 50
	Pavlu (1)		6.95	67.2	SW5	360 ± 90	1940 ± 170
	Pavlu (2)		6.76	51.5	SW6	160 ± 20	1760 ± 120
River	Büyüksu		7.88	13.4	R1	63 ± 16	196 ± 18
	Çatak		8.57	22.3	R2	80 ± 20	210 ± 20
	Sultanköy		8.45	16.6	R3	93 ± 24	522 ± 47
	Göynük		8.11	15.3	R4	50 ± 20	50 ± 10
	Mudurnu		8.21	15.5	R5	220 ± 50	540 ± 40
	Seben		8.25	18.1	R6	180 ± 40	490 ± 40
	Aladağ		8.40	16.3	R7	60 ± 10	150 ± 10
	Gerede		8.06	13.1	R8	50 ± 10	200 ± 20
	Abant		8.02	15.7	R9	30 ± 7	120 ± 10
	Kuruçay		8.03	15.8	R10	50 ± 16	297 ± 27
Mineral	Kökez		7.31	19.4	MW1	30 ± 10	430 ± 30
	Taşkesti		7.65	16.2	MW2	30 ± 10	40 ± 10
	Abant		8.15	10.6	MW3	43 ± 12	68 ± 16
	Çam		7.65	14.5	MW4	90 ± 10	220 ± 20
	Anatolya		6.68	18.5	MW5	30 ± 10	1860 ± 140
	Çepni		6.35	16.8	MW6	100 ± 20	200 ± 40
	Ömerler		6.52	15.8	MW7	180 ± 70	410 ± 120

2.2. Minimum detectable activity

The minimum detectable activity (MDA) is expressed as (Görür et al., 2011):

$$MDA\,(\mathrm{Bq\ L^{-1}}) = \frac{L_d}{VT\varepsilon 60} \tag{1}$$

with

$$L_d = 2.71 + 4.65\sqrt{C_B T} \tag{2}$$

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