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# Assessment of gross $\alpha$ and $\beta$ radioactivity for drinking water in Hatay province, Turkey

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ABSTRACT

In this study, the radioactivity analysis was performed in drinking water of Hatay province which is in the southeast region of Turkey. Using ten channels low-level proportional counter, the average "gross $\alpha$" and "gross $\beta$" activity concentrations of the 39 water samples were measured as 36.69 and 116.36 mBq/L, respectively. All values of the "gross $\alpha$" and "gross $\beta$" were lower than the limit values of 500 and 1,000 mBq/L, recommended by World Health Organization (WHO). The average annual effective doses were calculated to be 7.50 μSv for the $\alpha$-emitters and 58.61 μSv for the $\beta$-emitters. The results obtained in this study indicate that the *average* annual effective doses for all water samples are below the reference level as 0.1 mSv, recommended by WHO.

*Keywords:* Radioactivity; Gross $\alpha$; Gross $\beta$; Annual effective dose; Water; Hatay

## 1. Introduction

Radioactivity is a randomize event and occurs naturally through natural and artificial processes. The largest contribution to total radiation dose received by humans, comes from natural radiation. Therefore, environmental radioactivity measurements are necessary for determining the background radiation level due to natural radioactivity sources. The natural radiation consists of cosmic rays and terrestrial radiation. Terrestrial component is due to radioactive nuclides that are present in the air, water, soil, and building materials. The United Nations Scientific Committee on the Effects of Atomic Radiation estimates the global average human exposure from natural radiation sources as 2.4 mSv per year, and the radionuclides that are present in the drinking water are considered to be responsible for a comparatively small portion of this amount [1]. Therefore, the potential hazards of radioactive substances in the water are usually not regarded as a matter of public health concern, and the recommended approach adopted by the World Health Organization (WHO) is to set reference dose levels for the gross $\alpha$ and the gross $\beta$ radioactivities instead of assigning individual activity concentration limits for the different radionuclides that are present in the drinking water [2]. The measurements of the natural radioactivity in the air, soil, and drinking water

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samples from different geographic locations are continuously carried out in order both to establish a necessary background database and to assess the level of any possible contamination. Over the past two decades, some works to determine the radioactivity levels of drinking waters have been published both in Turkey and in the world [3–17].

Although lots of studies have been done on this issue not only in Turkey but also in other countries, no study has been seen for Hatay province so far. Therefore, the purpose of this study is to determine the gross-$\alpha$ and gross-$\beta$ activity concentrations in drinking water samples, collected from different locations throughout the province of Hatay, and then assess the risk to human life by consumption of the water from these sources.

## 2. Material and methods

### 2.1. Sampling area

Hatay, the southeast province of Turkey, is at the board of Syria. It is located between 35˚52´ and 37˚04´ N as latitudes and 35˚40´–36˚35´E as longitudes. Highest pick is Migirtepe (2,240 m) and other picks are Mount Ziyaret and Cebel Akra, Cassius (1,739 m). The territory of Hatay is covered by 46% mountain, 33% plain, 20% plateau and hillside. The Orontes River rises in the Bekaa Valley in Lebanon and runs through Syria and Hatay, where it reserves the Karasu and the Afrin River. It flows into the Mediterranean at its delta in Samandag. There was a lake in the plain of Amik but this was drained in the 1970s and today Amik is now the largest of plains and an important agricultural center. The climate is typical of the Mediterranean, with warm wet winters and hot, dry summers. The mountainous areas inland are drier than the ones along the coast. There are some mineral deposits; İskenderun is home to Turkey’s largest iron and steel plant, and the district of Yayladagi produces a colorful marble called Rose of Hatay. Average temperature in Hatay region is 24.08˚C, and average rainfall is 65 mm. The region spans an area of 5,403 $km^2$ and with a population of about 1.5 million [18]. The map of Hatay is shown in Fig. 1.

### 2.2. Sample collection

In order to measure the radioactivity levels in drinking water, 39 samples were collected from selected locations in Hatay and were transported to the laboratory in 1.5 L plastic bottles. Then, the tap water samples were acidified with $HNO_3$ to pH 2 in order to prevent any loss by absorption of radionuclides at the container walls and to reduce growth of microorganisms. Sample collection points are shown in Fig. 1.


Fig. 1. Sample collection points in Hatay province.

### 2.3. Experimental setup

The activity concentrations of the gross $\alpha$ and the gross $\beta$ in the tap water samples were measured using a gas proportional $\alpha/\beta$ counter of low background multiple detector type (Berthold LB 770). LB 770 10-Channel $\alpha/\beta$ Low-Level Counter offers simultaneous $\alpha$–$\beta$ measurement of 10 planchets. For each sample, there are two separate measuring channels for $\alpha$ and $\beta$ activities. Slider and counter tubes are surrounded by a 100 mm thick shielding made of machined lead bricks to reduce ambient radiation. The background of each detector was determined by counting an empty planchet for 1,000 min. The calibration of the low-level counting system used in the measurements was carried out with standard solutions that contained known activities of $^{241}Am$ for $\alpha$s and $^{90}Sr$ for $\beta$s which were similar to the sample geometry.

### 2.4. Minimum detectable activity

The minimum detectable activity (MDA) was calculated [19] using the below equation:

$$\text{MDA (Bq/L)} = \frac{L_d}{60 \times V \times T \times \varepsilon} \quad (1)$$

where $\varepsilon$ is the counting efficiency, $T$ is the duration of the measurements (in min), $V$ is the sample volume in liter and $L_d$ was defined as $L_d = 2.71 + \sqrt{C_B \times T}$. In here, $C_B$ is the background level in counts/min. In the given study, the MDA for the gross $\alpha$ and the gross $\beta$ were calculated as 7 and 8 mBq/L, respectively.

### 2.5. Measurement of the gross α in tap water samples

The activity concentrations of the gross $\alpha$ of the tap water samples were measured using the SM 7,110 precipitation method. 250 mL aliquot of each sample was transferred to a beaker. Two to three drops of a dilute detergent were added to the prepared aliquot. The beaker, placed on a hot-plate magnetic stirrer, was mixed by adding 20 mL of 2 N $H_2SO_4$. This stirring process was continued for 10 min after boiling to ensure a good mixing of the solution. Then, 0.5 mL of a barium carrier was added to the solution and the stirring process was continued for 30 min. 0.5 mL of Bromocresol purple indicator, 1 mL of iron carrier, and 5 mL of a paper pulp/water mixture was added. Then, drops of 6 M $NH_4OH$ were added until the color of the solution turned from yellow to purple, and the stirring process was again continued for a duration of 30 min more. Then, the solution was allowed to stand for precipitation. The precipitate was then filtered with a vacuum pump through a filter paper. Finally, the precipitate was dried under an infrared lamp. The residue was counted twice for a period of 100 min. The gross $\alpha$ activity concentration was determined by taking the average result of two counts. The above-mentioned procedure was repeated for each water sample.

### 2.6. Measurement of the gross β in tap water samples

The measurements of the activity concentrations of the gross $\beta$ in the ground water samples were performed using the EPA 900 evaporation method. 250 mL aliquot of each sample prepared in a beaker was first acidified by 2–3 mL $HNO_3$, and the solution was then evaporated to a volume of 5–10 mL on a hot–plate. The solution was transferred on a tarred 6 cm diameter steel planchet and dried in an oven at 105°C for at least 2 h. The sample residue was cooled in desiccators for about 30 min followed by weighing of the sample. The residue was counted twice for a period of 500 min. The gross $\beta$ activity concentration was determined by taking the average result of two counts. The above-mentioned procedure was repeated for each water sample.

## 3. Results

The measured results of gross-$\alpha$ and $\beta$-activities from the water samples which were collected from

Table 1
Gross $\alpha$ and gross $\beta$ radioactivity concentrations in drinking waters of Hatay

| No | Sample name | Gross $\alpha$ [mBq/L] | Gross $\beta$ [mBq/L] |
|---|---|---|---|
| 1 | Akbez | 28 ± 11 | 100 ± 18 |
| 2 | Aktepe | 21 ± 13 | 61 ± 11 |
| 3 | Antakya | 36 ± 12 | 43 ± 17 |
| 4 | Ardıçlı | 50 ± 14 | 70 ± 17 |
| 5 | Arsuz-I | 16 ± 7 | 40 ± 12 |
| 6 | Arsuz-II | 45 ± 18 | 66 ± 22 |
| 7 | Batıayaz | 13 ± 5 | 50 ± 10 |
| 8 | Belen-I | 52 ± 19 | 134 ± 23 |
| 9 | Belen-II | 40 ± 14 | 110 ± 17 |
| 10 | Çabala | 76 ± 16 | 172 ± 22 |
| 11 | Deliçay | 22 ± 9 | 116 ± 17 |
| 12 | Döver | 10 ± 7 | 38 ± 17 |
| 13 | Eriklikuyu-I | 27 ± 11 | 55 ± 7 |
| 14 | Eriklikuyu-II | 14 ± 8 | 97 ± 30 |
| 15 | Erzin-I | 10 ± 4 | 392 ± 52 |
| 16 | Erzin-II | 35 ± 17 | 89 ± 23 |
| 17 | Hacılar-I | 30 ± 8 | 102 ± 13 |
| 18 | Hacılar-II | 11 ± 5 | 61 ± 13 |
| 19 | Hassa Mrk | 33 ± 13 | 101 ± 38 |
| 20 | Hıdırbey | 49 ± 12 | 103 ± 25 |
| 21 | İskenderun-I | 10 ± 8 | 28 ± 14 |
| 22 | İskenderun-II | 33 ± 21 | 76 ± 40 |
| 23 | Kapısuyu-I | 41 ± 14 | 75 ± 24 |
| 24 | Kapısuyu-II | 13 ± 6 | 54 ± 13 |
| 25 | Kapısuyu-III | 65 ± 19 | 84 ± 18 |
| 26 | Karaköse | 36 ± 2 | 949 ± 52 |
| 27 | Kırıkhan-I | 24 ± 7 | 94 ± 14 |
| 28 | Kırıkhan-II | 11 ± 6 | 55 ± 14 |
| 29 | Leylekli-I | 31 ± 11 | 48 ± 28 |
| 30 | Leylekli-II | 57 ± 31 | 50 ± 15 |
| 31 | Reyhanlı | 64 ± 17 | 156 ± 25 |
| 32 | Sebenoba | 58 ± 20 | 263 ± 46 |
| 33 | Sofular | 82 ± 18 | 44 ± 33 |
| 34 | Söğüt | 36 ± 9 | 75 ± 26 |
| 35 | Şenköy | 61 ± 17 | 135 ± 21 |
| 36 | Vakıflı | 38 ± 10 | 54 ± 11 |
| 37 | Yayladağı | 86 ± 18 | 186 ± 22 |
| 38 | Yoğunoluk | 50 ± 13 | 98 ± 20 |
| 39 | Yukarı Okçular | 17 ± 14 | 14 ± 9 |

Hatay region are shown in Table 1. It is seen that the β-activities are commonly higher than the measured α-activities. The gross α-activity varies between 10 and 86 mBq/L and its average activity value is 36.69 mBq/L. The standard deviation of gross α-activity is obtained as 20.69 mBq/L. On the other hand, the gross β-activity varies from 14 to 949 mBq/L and its average value is 116.36 mBq/L. The standard deviation of gross β-activity is 150.71 mBq/L. At a glance, β-activities for Erzin-I and Karaköse; 392 and 949 mBq/L, respectively, are much higher than the other sampling points, but they are still under the limit (1,000 mBq/L). The water sample of Erzin-I was taken from a place close to the source of thermal water which may contain some radionuclides. Hence, this may be the reason for its high value. Karaköse is a small town that is settled in Yayladagi District, surrounded by mountains with high altitude. It is possible that the sample of Karaköse may contain different kind of mountain source waters and this may be the reason for its high value, too. Some of the statistical values for gross α and gross β-radioactivity levels of waters in Hatay are shown in Table 2.

The gross α- and β-activities obtained here are mostly lower than the limit values which are 500 mBq/L for α activity and 1,000 mBq/L for β activity WHO. In addition, as seen in Table 3, the average values of gross α- and β-activities are generally comparable with the values obtained from different cities of Turkey, as well as some other countries. The obtained activity results are much lower than recommended activity levels for drinking water by WHO, therefore, no action is generally needed toward reducing the radioactivity of drinking waters in Hatay [2]. When Hatay's results are compared with the previously published results obtained from different Turkish cities ([3–12]), Hatay' s results are found to be among them. The annual effective doses were also calculated using formulas [2] given below and the results are shown in Table 4. In order to find annual effective doses, the

Table 2
Statistics of gross α-and gross β-radioactivity concentrations in waters of Hatay

| | Gross α (mBq/L) | Gross β (mBq/L) |
|---|---|---|
| Number of measurements | 39 | 39 |
| Minimum | 10 | 14 |
| Maximum | 86 | 949 |
| Mean | 36.69 | 116.36 |
| Standard deviation | 20.69 | 150.71 |

Table 3
Comparison of average values of both gross α and gross β radioactivity levels obtained in this with literature

| | Gross α (mBq/L) | Gross β (mBq/L) |
|---|---|---|
| Hatay (present study) | 36.69 (10–86) | 116.36 (14–949) |
| Adana [3] | 96 | 86 |
| Bayburt [4] | 63 | 39 |
| Bursa [5] | 68.5 | 67.1 |
| Canakkale [6] | 59.9 (17.9–296) | 84.1 (40.5–199) |
| Gaziantep [7] | 49.3 (6.5–302.6) | 128.4(19.8–418.3) |
| Giresun [8] | 7.1 | 97.1 |
| Istanbul [9] | 22.8 (7–45) | 66.4 (20–130) |
| Kastamonu [10] | 8.9 (1.4–26) | 271 (16.2–2,241) |
| Sanliurfa [11] | 38 (1.8–432.3) | 132.4 (6–924.7) |
| Tekirdag [12] | 44 | 100 |
| WHO action level [2] | 500 | 1,000 |
| Brasil [13] | 1–400 | 120–860 |
| Central Italy [14] | 18.18–128.18 | 41.57–258.59 |
| Hungary [15] | 35–1,749 | 33–2015 |
| Italy [16] | 8–349 | 25–273 |
| Spain [17] | 30–880 | 40–2,280 |

Note: The data in parentheses are the corresponding ranges.

Table 4
Annual effective doses from $\alpha$ and $\beta$ emitters, in waters of Hatay

| No | Sample name | Annual dose from $\alpha$ (μSv) | Annual dose from $\beta$ (μSv) |
|---|---|---|---|
| 1 | Akbez | 5.72 | 50.37 |
| 2 | Aktepe | 4.29 | 30.73 |
| 3 | Antakya | 7.36 | 21.66 |
| 4 | Ardıçlı | 10.22 | 35.26 |
| 5 | Arsuz-I | 3.27 | 20.15 |
| 6 | Arsuz-II | 9.20 | 33.24 |
| 7 | Batıayaz | 2.66 | 25.19 |
| 8 | Belen-I | 10.63 | 67.50 |
| 9 | Belen-II | 8.18 | 55.41 |
| 10 | Çabala | 15.53 | 86.64 |
| 11 | Deliçay | 4.50 | 58.43 |
| 12 | Döver | 2.04 | 19.14 |
| 13 | Eriklikuyu-I | 5.52 | 27.70 |
| 14 | Eriklikuyu-II | 2.86 | 48.86 |
| 15 | Erzin-I | 2.04 | 197.45 |
| 16 | Erzin-II | 7.15 | 44.83 |
| 17 | Hacılar-I | 6.13 | 51.38 |
| 18 | Hacılar-II | 2.25 | 30.73 |
| 19 | Hassa Mrk | 6.75 | 50.87 |
| 20 | Hıdırbey | 10.02 | 51.88 |
| 21 | İskenderun-I | 2.04 | 14.10 |
| 22 | İskenderun-II | 6.75 | 38.28 |
| 23 | Kapısuyu-I | 8.38 | 37.78 |
| 24 | Kapısuyu-II | 2.66 | 27.20 |
| 25 | Kapısuyu-III | 13.29 | 42.31 |
| 26 | Karaköse | 7.36 | 478.01 |
| 27 | Kırıkhan-I | 4.91 | 47.35 |
| 28 | Kırıkhan-II | 2.25 | 27.70 |
| 29 | Leylekli-I | 6.34 | 24.18 |
| 30 | Leylekli-II | 11.65 | 25.19 |
| 31 | Reyhanlı | 13.08 | 78.58 |
| 32 | Sebenoba | 11.86 | 132.47 |
| 33 | Sofular | 16.76 | 22.16 |
| 34 | Söğüt | 7.36 | 37.78 |
| 35 | Şenköy | 12.47 | 68.00 |
| 36 | Vakıflı | 7.77 | 27.20 |
| 37 | Yayladağı | 17.58 | 93.69 |
| 38 | Yoğunoluk | 10.22 | 49.36 |
| 39 | Yukarı Okçular | 3.48 | 7.05 |

daily water consumption of adult was assumed that 2 L per day. The average annual doses were calculated as 7.50 and 58.61 μSv from $\alpha$ and $\beta$ emitting radionuclides, respectively. Both of these values are lower than 100 μSv per year that is suggested by WHO. These results indicate that there is no risk dealt with water of Hatay region.

$$\text{AED}\ (\mu\text{Sv}) = (2.8 \times 10^{-4}) \times A \times 2\,\text{L} \times 365 \quad \text{for}\ \alpha \qquad (2)$$

$$\text{AED}\ (\mu\text{Sv}) = (6.9 \times 10^{-4}) \times A \times 2\,\text{L} \times 365 \quad \text{for}\ \beta \qquad (3)$$

where AED is annual effective dose in μSv, $A$ is activity concentration in mBq/L, $2.8 \times 10^{-4}$ and $6.9 \times 10^{-4}$ are the conversion coefficients (mSv $\text{Bq}^{-1}$), for $\alpha$ emitter and $\beta$ emitter, respectively. An adult, on the average, consumes 2 L of water per day [2].

## 4. Conclusions

This study presents the radioactivity levels for drinking waters collected from Hatay province located in the southeast region of Turkey. The measured average gross $\alpha$-activity is 36.69 mBq/L and average gross

$\beta$-activity is 116.36 mBq/L. They are comparable with the data obtained for a few Turkish cities [5,9]. When these values are compared with the data obtained from the neighboring cities of Hatay province [3,7,11] it is seen that the $\alpha$ activity of Hatay region is lower than both Adana and Gaziantep. On the other hand, the $\beta$ activity of Hatay region is lower than Gaziantep but higher than Adana. When the values obtained in this study are compared with the data of Mediterranean countries [16,17] we have seen that both $\alpha$- and $\beta$-activities are commonly closer to them. The obtained activity levels are lower than the recommended limit values for the drinking water set by WHO. The average annual effective doses from $\alpha$ and $\beta$ obtained from these activities are 7.50 and 58.61 μSv, respectively. They are again lower than the recommended limit values suggested by WHO. Therefore, the detailed radionuclide analyses of the studied samples are not performed in this study. In conclusion, the activities were measured and then the radiation doses were estimated for all water ingestion. The total dose for adults did not exceed WHO recommended limit value. The data obtained in this study are baseline for the future studies which would be used to evaluate possible changes. It should provide a good baseline for setting standards for the water quality in this country. It could be said that there is no risk to human health, sourced from the drinking water in Hatay.

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