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İZMİR-ÇEŞME SAHİLLERİNİN DOĞAL RADYOAKTİVİTESİ

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ÖZ

Türkiye, Avrupa'nın en büyük plaj kum sistemine sahip ülkesidir. 8333 km uzunluğundaki (toplam sahilin yaklaşık % 10'u) toplam sahillerin 845 km'lik kısmı plaj kumları ile kaplıdır. Plaj kumları mineral yatakları olup genellikle magmatik kayaçlardan kaynaklanmaktadır. Dolayısıyla, plaj kumlarındaki doğal radyoaktivite çalışmaları, dışsal maruz kalınan gamma radyasyonuna bağlı riski belirlemek için önemlidir.

Bu çalışmada, Çeşme ilçesi kıyı şeridi boyunca alınan plaj kum örneklerinin doğal radyonüklid (^{226}Ra, ^{232}Th, ^{40}K) aktivite konsantrasyonları HPGe gamma spektrometresi sistemi ile ölçülmüş ve insanların maruz kaldığı doz oranları hesaplanmıştır. Plaj kumlarının ^{226}Ra, ^{232}Th, ^{40}K aktivite konsantrasyonları sırasıyla, 5.70–38.83, 3.870–292.7 ve 120.4 – 377.6 Bq/kg aralığında olduğu ölçülmüş ve absorbe edilen gamma doz hızları 12-202 nGy/h aralığında olduğu hesaplanmıştır. Yıllık etkin doz eşdeğer oranları 0.015-0.250 mSv aralığında olduğu bulunmuştur. Kum örneklerinin radyum eşdeğer aktivite değerleri, dünya limit değeri olan 370 Bq/kg'dan düşük bulunmuştur, Çeşme-Alaçatı'daki bir plaj hariç. Elde edilen sonuçlar, Çeşme kıyı şeridindeki radyoaktivite ve doz oranlarının nüfus açısından herhangi bir risk oluşturmadığını göstermektedir.

Anahtar Kelimeler: *Doğal radyoaktivite, plaj kumu, doz hızı, kıyı şeridi, Çeşme*

NATURAL RADIOACTIVITY OF THE COASTLINE OF ÇEŞME-İZMİR

ABSTRACT

Turkey has the largest beach sand system in Europe. The 845 km part of total coasts in 8333 km length (about 10% total coast) is covered by beach sands. Beach sands are mineral deposits, originated generally in the magmatic rocks. Therefore, the study of natural radioactivity in beach sands is important to assess the radiological risk due to external exposure to gamma radiation.

In this study, the activity concentrations of natural radionuclides (^{226}Ra, ^{232}Th, ^{40}K) of beach sand samples taken along the coastline of Çeşme district were measured by HPGe gamma

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spectrometry system and the dose rates exposed by people were calculated. The activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K in beach sand are found to lie in the range of 5.70 –38.83, 3.870–292.7, 120.4-377.6, dry weight, respectively. The absorbed gamma dose rate has been calculated to be in the range between 12 and 202 nGy/h. The annual effective dose equivalents are within 0.015-0.250 mSv. The radium equivalent values of beach sand samples are found lower than the world limit of 370 Bq/kg with the exception of a beach in the Alaçatı-Çeşme. The obtained results show that the radioactivity and the dose rates of Çeşme coastlines do not pose any risk for population.

Keywords: *Natural radioactivity, beach sand, dose rate, coastline, Çeşme*

Introduction

The main purpose or measuring the natural radiation level in the environment is to determine the dose of radiation that people receive from natural sources, and to evaluate the risks for people's health due to this radiation. The annual average effective dose received from natural radiation sources is 2.4 mSv (UNSCEAR, 2000). A major part of this is composed of primordial radionuclides such as ^{238}U and ^{232}Th series and their products, and ^{40}K. The external exposure due to primordial radionuclides results in an annual effective dose equivalent to 0.48 mSv. Because people are routinely to radiation in environments in which they live, the extra effect on human life and public health from radiation doses taken from natural sources is extremely important. Therefore, to measure the natural radioactivity in regions where people live and frequent, is a requirement.

Environmental studies related to the measurement of the received dose levels of radiation have improved over the last 30 years. These studies performed in various parts of the world have particularly increased in importance as a natural consequence of a variety in activity concentrations of the primordial radionuclides in soil, sand, rocks, and building materials, due to the local geology of each region. In these studies, the natural radioactivity levels in different materials were measured, and dose radiation maps were drawn.

In spite of many studies (Alam et al., 1999; de Meijer et al., 2001; Kannan et al., 2002; Freitas and Alencar, 2004; Sengupta et al., 2005; El-Arabi, 2005; Seddeek et al., 2005; Lakshmi et al., 2005; Alencar and Freitas, 2005; Veiga et al., 2006; Vassas et al., 2006;

Mahur et al., 2008; Newman et al., 2008; Shetty and Narayana, 2010; Anjos et al., 2010; Malain et al., 2010; Al-Trabulsy et al., 2011; Malain et al., 2012; Zare et al., 2012; Ramasamy et al., 2013; SureshGandhi et al., 2013; Tari et al., 2013; Shuaibu et al., 2017) regarding radioactivity levels and doses on coastlines in various parts of the world, there have been a limited number carried out relating to (Aytekin et al. 2015; Özmen et al. 2014; Korkulu and Özkan 2013; TAEA, 2013; Cetiner et al. 2011; Yalçın 2009; Karayel et al. 2009; Baba et al., 2008; Örgün et al. 2007) the issues in Turkey.

Beach sands are a kind of mineral deposit, which are composed of volcanic rocks abounding in minerals containing U and Th such as granite, rhyolite, and andesite. These minerals emerge due to the erosion of rocks, relocated by the weather conditions, an accumulation at seafronts, and a rise in affluence. The regional enrichment of natural radioactivity in beach sands is a phenomenon observed worldwide. Radiation dose levels of beach sands which contain minerals abounding in high concentrations of uranium and thorium such as monazite and zircon are considerable. It is a fact that there are some areas of high background radiation particularly on the coastlines of Karnataka, Tamilnadu, Orissa and Kerala, which are regions of monazite-rich sand deposits in India (Shetty and Narayana, 2010). The other monazite-rich sand deposits are found in Brazil (Bahia) and Chine (Yangjiang) (Shuaibu et al., 2017). Therefore, the study of natural radioactivity and their distribution in beach sands is important to assess the radiological risk due to external exposure to gamma radiation.

In this study, natural radionuclide (^{226}Ra, ^{232}Th, ^{40}K) activity concentrations of beach sand samples along the Çeşme Peninsula coastlines, which are popular tourism centers in Turkey, were measured by means of a gamma spectrometry system, including the HPGe detector, and the dose rate values were calculated utilizing the resulting radionuclide activity concentrations that both permanent and temporary residents are exposed to. All the results obtained were also compared to the average worldwide values shown in the UNSCEAR 2000 report, and derived from other studies performed Turkey and worldwide.

Material and method

The geological structure of the area of study

According to geological research conducted in the Çeşme–Karaburun peninsula, the oldest unit is found to be composed of

Triassic–Cretaceous limestones. In spite of the fact that the peninsula lies along an east–west direction; it has a particular topographical lineup and structural configuration along the north–south one. This fundamental unit that can be observed is covered with a Neogene volcanic structure and Neogene sedimentary units such as marl, sandstone, sandy limestone, and conglomerate layers. All of these lithological units were broken due to tectonic forces, and have either inclined towards different directions, or ascended and descended. A geological map of the practice area of the Çeşme and Urla towns is shown in Figure 1 (Çakmakoğlu and Bilgin, 2006). As can be seen on this map, the coastline of Çeşme town is composed of Neogene structured volcanics and terrestrial unseparated (integral) structures. Volcanic originated andesites are seen in the region called Reisdere. There are Jura integral structures in the Ildır region in Çeşme. Reisdere. There are Jura integral structures in the Ildır region in Çeşme (Figure 1).

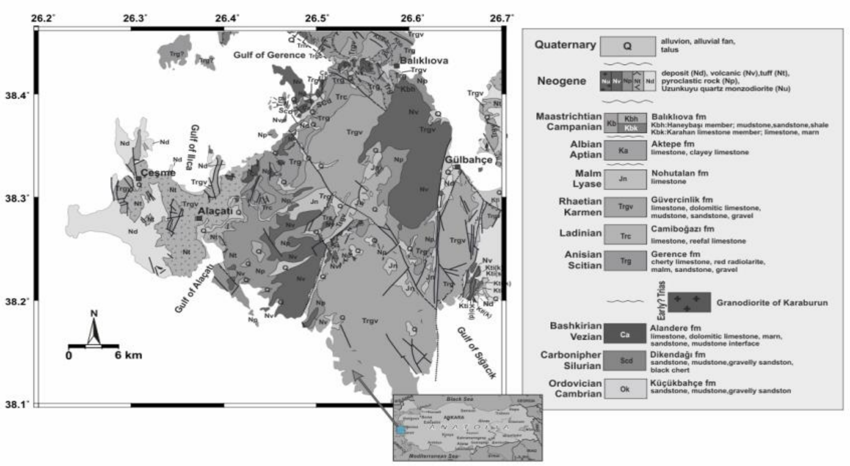

Figure 1. The geological map of the practice area of Çeşme town is shown in (Çakmakoğlu and Bilgin, 2006).

Sampling in the area of study

In this study, which was performed along Çeşme coastlines, beach sand samples were taken from everywhere that provides the sampling process with the inclusion of 66 sand samples taken from Çeşme beaches (Alaçatı, Ovacık, Altınkum, Pırlanta, Çiftik, Teke, Dalyan, Ilıca, Paşalimanı, Şifne, Reisdere, and Ildır). Each sample was taken from 10 cm deep and arranged to be in a state of 2 kg in weight. Coordinate codes of the samples were recorded via GPS (Figure 2).

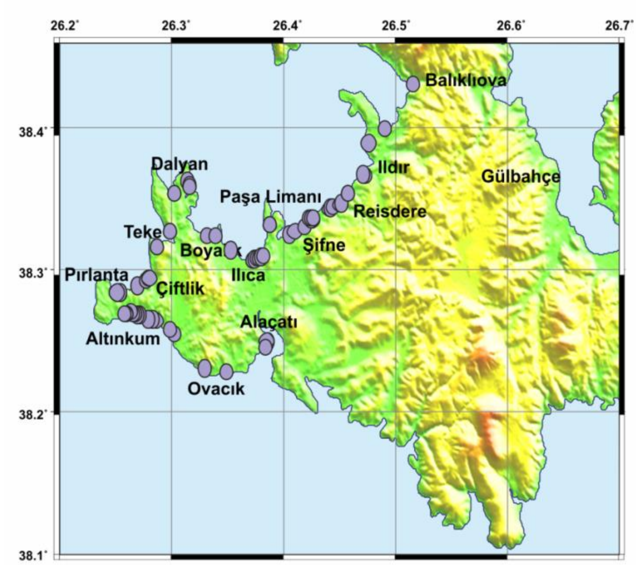

Figure 2. Samples taken from the study area are shown in.

Gamma spectrometer system

After bringing the laboratory samples, which were collected from the beaches within the scope of this study, the foreign substances (garbage, plastic, glass, etc.) among them were expurgated. All the beach sand samples were crushed into grains less than 200 μm in diameter, and oven dried at 105ºC for 24 h in order to remove the moisture. The samples were then sieved and sealed in standard 1 L Marinelli beakers, which were closed as tightly as possible in order to limit the escape of radon. The samples were then stored for 4 weeks before counting so as to ensure that ^{238}U attained a radioactive equilibrium with their daughters. The radioactivity ^{226}Ra, ^{232}Th and ^{40}K in the beach sand samples were measured using gamma ray spectrometry consisting of an HPGe detector connected to a 16.384 channel multi-channel analyzer (MCA). The gamma spectrometry consisted of a p-type 184 cm^3 HPGe coaxial detector with a 25% relative efficiency, a 1.87 keV resolution, and a peak to a Compton ratio of 57:1, which all referred to a ^{60}Co line of 1.33 MeV. The detector was coupled with a PC-based 8K multi-channel analyzer with the associated software, and surrounded by a 10 cm thick lead wall internally lined up with a 1.5 mm copper foil in order to reduce the back scattering photon reacting with the detector. Before the measurement, the system was calibrated. This was done using ^{137}Cs and ^{60}Co radioactive sources, which produce gamma ray energy of 662, 1173 and 1332 keV respectively. With these sources it was possible to convert the channel number to an energy scale. The samples were counted for a period of 50.000 s, and the spectra were analyzed for the photo peaks of ^{226}Ra, ^{232}Th, ^{40}K. Prior to the measurement of the samples, the environmental gamma background in the laboratory was determined with an empty Marinelli beaker under identical measurement conditions. It was later removed from the measured γ -ray spectra of each sample. The ^{226}Ra concentration was determined from the gamma lines of 295 keV, 352 keV, 609 keV and 1765 keV, originating from ^{214}Pb and ^{214}Bi as the mean value of the results of these gamma lines. The concentration of ^{232}Th was determined from the gamma lines of 583 keV, 911 keV and 2614 keV from ^{208}Tl and ^{228}Ac respectively. The ^{40}K concentration was calculated from their 1461 keV gamma line.

Dose calculation

The absorbed gamma dose rate (D) in the air 1 m above the ground surface due to the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K was calculated using the formula by UNSCEAR (2000):

$$\mathbf{D}_{(nGy/h)} = 0.462 \cdot C_{Ra} + 0.604 \cdot C_{Th} + 0.0417 \cdot C_K \quad (1)$$

where C_{Ra}, C_{Th}, C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq kg^{-1}respectively.

The annual effective dose equivalent (AEDE) has to be obtained in order to test the health effect of those absorbed dose rates. Using the conversion coefficient from the absorbed dose in the air to the effective dose (0.7 Sv Gy^{-1}) and the outdoor occupancy factor (0.2) implied that 20% of the time was spent outdoors, as proposed in UNSCEAR 2000 Report. The AEDE was obtained from the following formula:

$$\mathbf{AEDE}_{(mSv/y)} = D_{(nGy/h)} \times 8766_{(h/y)} \times 0.2 \times 0.7_{(Sv/Gy)} \times 10^{-6} \quad (2)$$

As the distribution of ^{226}Ra, ^{232}Th and ^{40}K in soils and rocks is not uniform, the uniformity with respect to the exposure to radiation was defined in terms of the radium equivalent activity (Ra_{eq}) in

Bq/kg. To compare the specific activity of the materials containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K, the following equation is used (Beretka and Mathew 1985):

$$\mathbf{Ra_{eq}}\,(Bq/kg) = C_{Ra} + 1.43\ C_{Th} + 0.077\ C_K \quad (3)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bq kg^{-1}. It is assumed that 370 Bq kg^{-1} of ^{226}Ra, 259 Bq kg^{-1} of ^{232}Th and 4810 Bq kg^{-1} of ^{40}K produce the same gamma ray dose rate (UNSCEAR, 1982).

Beretka and Mathew (1985) defined two other indices that represent external and internal radiation hazards, respectively. The external hazard index (H_{ex}) is obtained from Ra_{eq} and it is calculated by the following equation:

$$\mathbf{H_{ex}} = C_{Ra}/370 + C_{Th}/259 + C_K/4810 \le 1 \quad (4)$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively, in Bq/kg.

Results

The average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, the absorbed dose rates, the annual effective dose equivalent, the radium equivalent activities, and H_{ex} calculated are given in Table 1. ^{226}Ra, ^{232}Th and ^{40}K activity concentrations of beach sands are within the range of from 5.70 to 38.83 Bq/kg; from 3.870 to 292.7 Bq/kg; from 120.4 to 377.7 Bq/kg; as averages 18.2 Bq/kg, 51.5 Bq/kg and 222.2 Bq/kg, respectively in Table 1. The absorbed dose rates calculated by the means of the transformation coefficients presented in the UNSCEAR 2000 report are within a range between 12 to 202 nGy/h and 48.8 nGy/h on average. The annual effective dose equivalents are found in the range of 0.015-0.25 mSv/y and as an average of 0.060 mSv/y. The radium equivalent activity concentrations are within the range from 25 to 469 Bq/kg and 109 Bq/kg on average. The external hazard indexes are within the range from 0.07 to 1.27 and as an average of 0.29.

Table 1. The average activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K, in the beach sand samples, the absorbed dose rates (D), the annual

effective dose equivalent (AEDE), the radium equivalent activity (Ra_{eq}), the external hazard index (H_{ex}) on different beaches in Çeşme.

Beaches(Number of Samples)	**Average activity concentrations**(Bq/kg)			**Absorbed Dose Rate** (nGy/h)				**AEDE**	Ra_{eq}	
	^{226}Ra	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K	Total dose	(mSv/y)	(Bq/kg)	H_{ex}
Alaçatı (5)	24.22	292.7	348.1	11.2	177	14.5	202	0.250	469	1.27
Ovacık (3)	21.12	54.20	297.8	9.76	32.7	12.4	55	0.067	122	0.33
Altınkum (12)	11.51	48.71	166.7	5.32	29.4	6.95	42	0.051	94	0.25
Pırlanta (4)	5.70	3.870	175.8	2.63	2.34	7.33	12	0.015	25	0.07
Çiftlik (5)	13.60	100.1	165.3	6.29	60.5	6.89	74	0.090	169	0.46
Teke (4)	13.56	14.93	169.3	6.26	9.02	7.06	22	0.027	48	0.13
Dalyan (5)	12.81	46.35	162.6	5.92	28.0	6.8	41	0.050	92	0.25
Boyalık (3)	24.75	33.67	253.0	11.4	20.3	10.6	42	0.052	92	0.25
Ilıca (7)	38.83	7.274	120.4	17.9	4.39	5.02	27	0.034	58	0.16
Paşalimanı (2)	14.29	13.30	176.4	6.60	8.03	7.35	22	0.027	47	0.13
Şifne (3)	25.77	26.38	377.6	11.9	15.9	15.7	44	0.053	93	0.17
Reisdere (10)	18.47	17.63	289.2	8.53	10.6	12.1	31	0.038	66	0.24
Ildır (3)	12.27	10.43	186.4	5.67	6.30	7.77	20	0.024	42	0.11

The average activity concentrations of ^{226}Ra, ^{232}Th, ^{40}K and dose rates are also shown in Figures 3-9. In comparison with the average values presented in the UNSCEAR 2000 report, the acquired activity concentration values of ^{226}Ra are below the global value, which was 35 Bq/kg, except in the one region of Ilıca (Figure 3). It was observed that the beach zone in Ilıca was composed of alluvium and high radium activity concentrations that were measured. This region is located on an active fault zone that there are many geothermal springs. The activity concentrations of ^{232}Th are below the global average value of 30 Bq/kg except in the six regions of Alaçatı, Ovacık, Altınkum, Çiftlik, Dalyan and Boyalık (Figure 4). These regions are located on volcanic rocks which consist of pyroclastic and tuff materials. These kinds of rocks have high thorium activity concentration. However, these high thorium activity results are both acceptable and normal. When the ^{40}K activity concentrations are examined it is seen that the values are below the global average value of 420 Bq/kg (Figure 5).

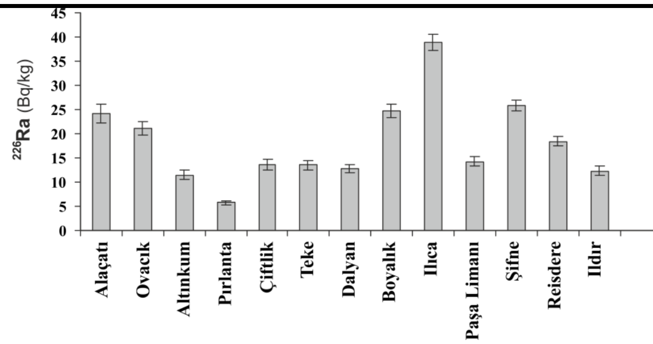

Figure 3. The average activity concentrations of ^{226}Ra in the beach sand samples collected from the different beaches in Çeşme.

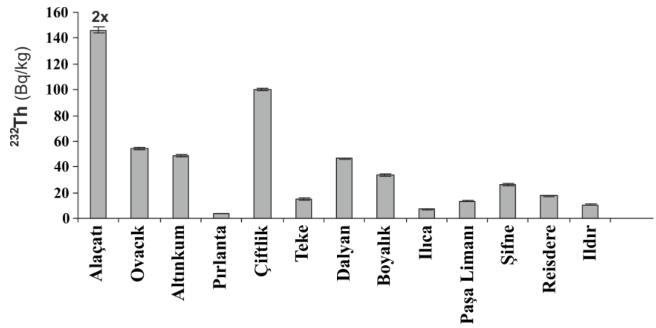

Figure 4. The average activity concentrations of ^{232}Th in the beach sand samples collected from the different beaches in Çeşme.

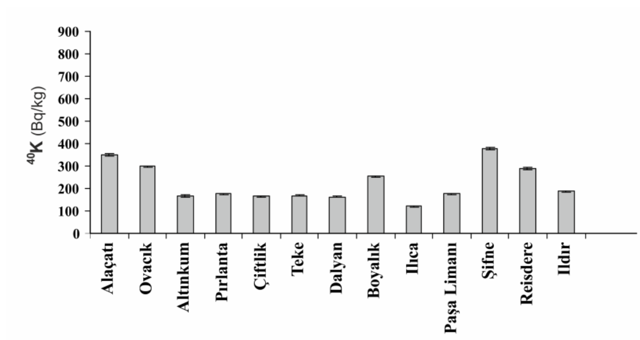

Figure 5. The average activity concentrations of ^{40}K in the beach sand samples collected from the different beaches in Çeşme.

In comparison with the average values presented in the UNSCEAR 2000 report, the absorbed dose rates in the air due to the beach sand radioactivity of Alaçatı and Çiftlik are all above the officially agreed global value of 60 nGy/h (Figure 6). The highest contribution to the dose rates at the Alaçatı beach is derived from ^{232}Th over the percentage of 88. In addition, at the Çiftlik beach, the highest contribution to the dose rates is derived from ^{232}Th over the percentage of 83. Also, it is possible to observe that the annual effective dose equivalent value at the Alaçatı beach is approximately three times greater than the global average value of 0.074 mSv/y publicized in the UNSCEAR 2000 report (Figure 7). The annual effective dose equivalent obtained from the other beaches, excluding the ones at Alaçatı and Çiftlik are below the global average value. The radium equivalent values of all the beaches, except Alaçatı, are all below the accepted limit value of 370 Bq/kg (Figure 8). Similarly, when the H_{ex} results are examined, it can be seen that the highest value (1.27) is measured in the Alaçatı beach (Figure 9). The H_{ex} values in all other beaches are smaller than 1 (one).

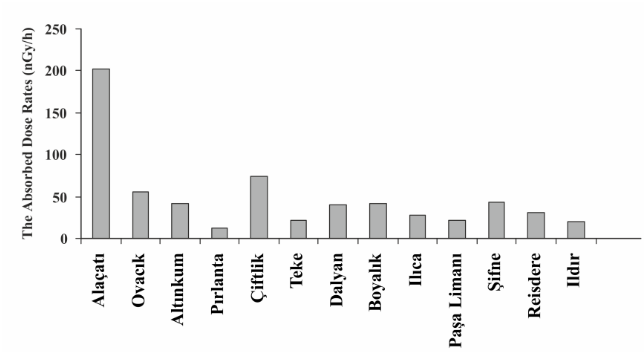

Figure 6. The absorbed dose rates of Çeşme coastlines.

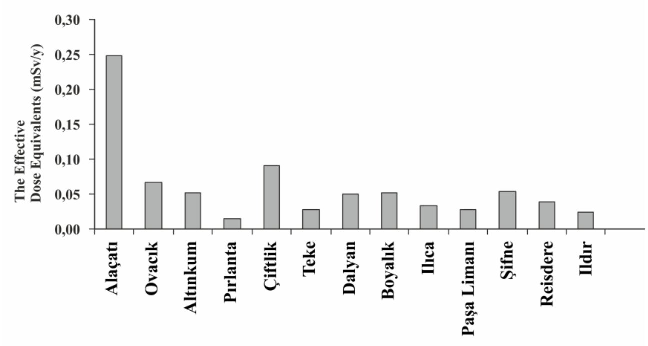

Figure 7. The annual effective dose equivalents of Çeşme coastlines.

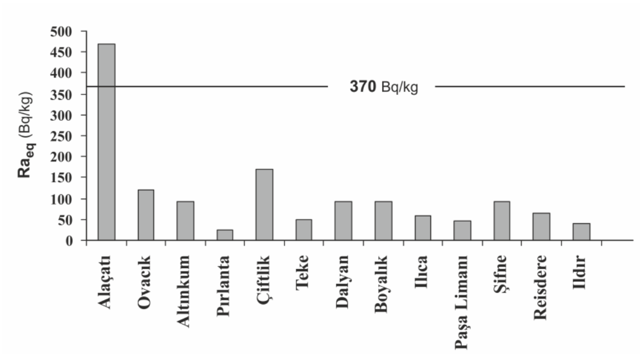

Figure 8. The radium equivalent values of Çeşme coastlines.

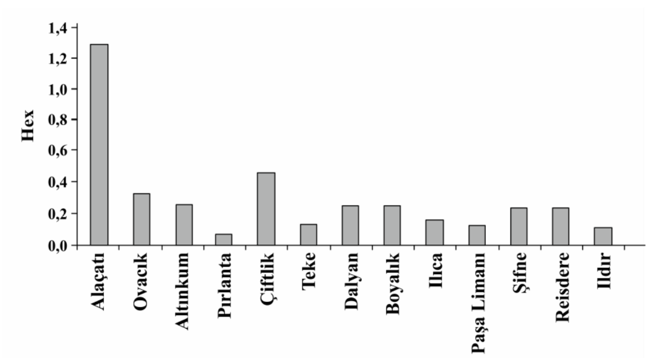

Figure 9. The external hazard indexes of Çeşme coastlines.

The results of the studies in worldwide and Turkey has been given in the Table 2. As can be seen from this table, the results obtained from the studies performed in India and Brazil is above the ones derived from this study. Also, the results derived from the studies performed in Thailand, Egypt, Iran and South Africa is also very similar to those derived from this study. Only very high activity concentrations were measured in two studies in the Çanakkale region (Çetiner et al. 2011; Örgün et al., 2007), from the results of our study and other studies of Turkey. These high activities are related to the Kestanbol granite in the Çanakkale region.

Table 2. Comparison of activity concentrations of ^{238}U (^{226}Ra), ^{232}Th and ^{40}K in the beach sand samples in Turkey and other areas in the world.

Location	**Number of samples**	**^{238}U or ^{226}Ra (Bq/kg)**	**^{232}Th (Bq/kg)**	**^{40}K (Bq/kg)**	**Reference**
Çeşme-Turkey	66	5.70–38.83	3.87-292.7	120.4–377.7	This study
Zonguldak	28	9.98-56.81	9.93-48.87	103.0-610.5	Aytekin et al., 2015
Antalya ve Mersin	30	4.0-21.5	1.8-27.9	19.0-590.3	Özmen et. al., 2014
Black sea coast of Kocaeli, Turkey	20	4.41-14.04	2.62-16.55	11.60-513.32	Korkulu and Özkan, 2013
Çanakkale, Turkey	9	383–8506	741 – 28894	624 – 2176	Cetiner et al. 2011
Bodrum, Turkey	12	2.25-71.47	25.75-42.81	510.17-835.28	Karayel et al. 2009
Ezine Region,	13	290.36	532.04	1160.75	Örgün et al.

Turkey					2007
Red Sea coast, Egypt	52	25.3–20.6	21.4–22.4	618-548	El-Arabi, 2005
North Sinai, Egypt	30	56.0	83.4	88	Seddeek et al. 2005
North east coast of Tamilnadu, India	10	35.12	713.6	349.6	Suresh-Gandhi et al. 2013
Kerala, India	39	170.4	547.3	117.2	Ramasamy et al. 2013
East coast of Tamilnadu, India	66	ND-254	13-3576	15-524	Lakshmi et al. 2005
Orissa, India	-	350	2000	200	Sengupta et al. 2005
Kalpakkam, India	9	36 - 258	352 - 3872	324 - 405	Kannan et al. 2002
The west and the east coast of southern Thailand	60	1.6-83.1	0.3-73.9	1.9-1375.6	Malain et al. 2010
Andaman coast, Thailand	6	2.7–23.5	3.0–34.5	10.7–654.3	Malain et al. 2012
West coast, South Africa	-	4.0	5.3	37.1	Newman et al. 2008
Rio de Janeiro,	168	4-80	5-216	51-570	Anjos et al.

Brazil					2010
Southeast coast, Brazil	-	5-4043	7-55537	25-888	Veiga et al. 2006
Ilha Grande, Brazil	10	5-176	2-235	102-1114	Alencar and Freitas 2005
Southeastern Brazil	24	6-180	12-349	47-527	Freitas and Alencar 2004
Ramsar, Iran	48	19.2	17.9	337.5	Tari et al. 2013
Northern coast of Oman Sea, Iran	36	11.83-22.68	10.7-25.02	222.89-535.07	Zare et al. 2012
USA	-	37	26	< 296	NCRP, 1975
World Average(Soil)	-	15	15	260	UNSCEAR,1982
	-	25 (10-50)	25 (7-50)	370 (100-700)	UNSCEAR, 1988
	-	40 (8-160)	35 (4-130)	370 (100-700)	UNSCEAR, 1993
	-	35	30	420	UNSCEAR, 2000

Conclusion

This work reports the level of natural radioactivity in 66 beach sands collected from Çeşme coastlines. All of the results obtained can be compared with the worldwide values given in the UNSCEAR 2000 report, with the exception of a beach in the Alaçatı-Çeşme region. In comparison with other studies that have been performed in different countries, except those performed in high background radiation areas, similar results have been obtained. Thus, the results achieved within the context of this study show that the radioactivity and dose rates in the Çeşme coastlines do not present any risk to the local population. In Turkey, an area surrounded by sea on three sides, a dense and active human population in terms of tourism exists along the coastlines; therefore, it is suggested that a detailed database be formed via studies to be performed along all the coastlines by taking this study as a reference.

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