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# Distribution of the Natural and Anthropogenic Radionuclides at Fethiye Gulf in the South Aegean

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**Abstract:** In this study, natural gamma radiation of beach sand deposits was measured along the coast of Fethiye Gulf (20 public beach), with the aim of studying the provenance and transport processes of sediments. Concentrations of thorium, uranium and potassium in the beach sands were evaluated using gamma-ray spectrometry. Furthermore, the beach sand sampling along the 100 km around the Fethiye Gulf allowed for evaluation of the radioactivity levels in terms of radiological risk assessments in this touristic region. Activity concentration of natural and anthropogenic radionuclides in Fethiye coast sediments have been resulted as the distribution of < 2 - 150±4 Bq/kg and rock activity concentrations have been emerged among the amounts of <1 - 157.48±15.36 Bq/kg.

## 1. Introduction.

Occurring of sediments have been resulted by corrosion of parent rock, deposition and sedimentation process. Beach sands which were residual as geological utterly have resisted to corrosion [1]. They have been deposited by resulting of river and wind removal and water flow near the sea side. However, mineralogical properties of beach sands have shown the story of primary rock formation. There are four types of radionuclide classes with respect to their origins which are; cosmic ray radionuclides such as $^{7}$Be and $^{14}$C, Primordial isotopes such as $^{232}$Th and $^{238}$U, artificially produced radionuclides $^{137}$Cs and $^{90}$Sr, natural decay products such as $^{226}$Ra and $^{222}$Rn [2].$^{238}$U and $^{232}$Th of products and $^{40}$K have taken their own place into rock, soil and sand related with the evaluation of geological background all around the world [3]. Uranium and thorium atoms have been into siliceous sediments as depending on ornament and dark coloured minerals[4]. While parent rock has been broken by the reasons are weather conditions and erosion U and Th can be deposited into dark coloured population and thin particles. Importance of heavy minerals(zircon, ilmenite, magnitite, garnet, monazite, rutile and etc. in sand should have been considered and they have comprised enriched uranium and thorium concentration[5] On the other hand, K has been enriched into K- feldspar and orthoclase. So, enriched of K should not have been expected during the process of transportation. Gamma activity of K will correspond to activity of parent rock. From this point of view, potassium can be described as the radioactive trace of the parent rock. As a result, primordial radionuclides "U, Th and K" have a major role of transportation of sediments in geological studies which are related with distribution of sediment composition and deposition. Gamma spectrometry has been applied on various areas such as lithologically mapping of rocks, mineral discovering, and transportation of sediment, test of nuclear weapon and study of nuclear waste. Gamma spectrometry is a radiometric technical based on gamma emission of primordial radionuclides. $^{238}$U, $^{232}$Th, $^{208}$TI and $^{214}$Bi are also radionuclides which generally can be used as gamma emitter except $^{40}$K.

One of the previous studies in radioactivity of sand beaches are; Sengupta and Saha,(2009); Kurt and Berker,(2014); Radenkovic et al.(2008); to the old studies, there has been a correlation between minerologic properties of sediment and natural radionuclides in sediment[6], [7], [8]. Ekpe and Essien (1999) have made a research on the engine oil related with gamma determination[9]. $^{226}$Ra, $^{232}$Th and $^{40}$K radionuclides have been observed in the minerals of sand beaches in Bangladesh according to study of Alam et al. (1999) [10]. Shetty and Narayana (2010) and Nada et al.(2012) have specified as the other researchers study on natural radioactivity [11], [12] . Mohanty et al. (2004) also have made same study on radionuclides of sand beaches in the south east of India[13] . Kannan et al. (2002) have carried out study of natural radionuclides upon soil

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and beach in Kalpakkam, India[14]. Korkulu and Ozkan (2013) have made a research on the radionuclides in the black sea cost of Kocaeli, Turkey[15]. Papadopoulos et al. (2015) have made a research on minerals of radioactivity concentration in North Greece[16]. Suresh-gandhi et al. (2013) have determined the distribution of gamma rays of radionuclides in the North east coast of Tamilnadu, India[17]. Vassas et al (2006) have done a research upon enrichment of radioactivity in France[18]. Freitas and Alencar (2004) carried out the distribution of radionuclides in Brazil[19]. Newman et al. (2008) have concluded their work on soil, sand natural radioactivity[20]. Kessaratikoon et. al (2015) have made a research on sand samples in Thailand[21]. This paper has demonstrated the radiometric analysis in the coast deposits of Fethiye and rock samples have been pointed out by the evaluating of radiological risk.

## 2. Material and method.

Study which has been carried out in Fethiye, evaluation of radionuclides distribution in sediment composition has been becomes a main idea of this article. According to this logic, all steps can be lined up as followings below;

- Evaluation of general geology
- Investigation of drainage system, river, morphology and hydrography in Fethiye
- Sampling coast sediments and rocks
- Radiometric analysis
- Data analysis.

### 2.1. Sampling and Study Area

Coast Sediments: Along the shore of Fethiye gulf, 20 sediment samplings have been obtained
Rocks: Serpentinite, neritic, pelagite (pelagic) rock sediments have been sampled related with geological formation of Fethiye gulf. All coordinates of samplings have been identified by gps Figure 2.1 has shown that all samplings which are sand sediments and rocks between the range of 100.88 km.

Preparation of samples: In this study, rocks have been crushed into jaw crusher machine in geology engineering department of Dokuz Eylul University. These rock samples and also sand samples were heated in $105^0$ C and dried around 24- 48 hours then put into marinelli beakers for radiometric analysis. These beakers have been waited 4 weeks for reaching radioactive balance between radium ($^{226}$Ra) and radon ($^{222}$Rn).

### 2.2 Analysis of radionuclides

Radionuclides which emitted gamma photons can be calculated as followings below;

$$A = \frac{\mathrm{P/ts}}{\varepsilon * f * m * k1 * k2 * k3 * k4 * k5} \quad (1)$$

$$P = \mathrm{Ns} - \frac{\mathrm{ts}}{\mathrm{tb}} * \mathrm{Nb} \quad (2)$$

$N_s$ = Space of peak which is determined in samples.
$N_b$= Other space of peak in spectrum.
$\boldsymbol{\varepsilon}$ = Yield of Eɣ in the peak which is being interested.
$t_s$= Count duration for samples.
$t_b$= Count duration out of samples.
m= mass for the samples which are dried.
f = Probability of gamma radiation per each emit in Eɣ.
$K_1$= Radiation fixing factor during the process collecting samples and detection of radionuclides.

$$K1 = \exp\left(-\frac{\mathrm{In}(2)*\Delta t}{\mathrm{t}\,1/2}\right) \quad (3)$$

Δt = The time of collecting samples and detection of samples as radionuclides.
$K_2$= Fixing factor of samples which is analyzed during the detection.

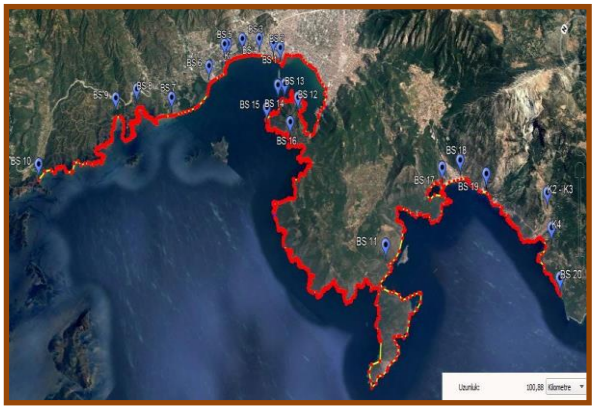
$$K2 = \frac{\mathrm{T}\,1/2}{\mathrm{In}\,2*\mathrm{Tr}}\left(1 - \exp\left(-\frac{\mathrm{In}\,2*\mathrm{Tr}}{\mathrm{T}1/2}\right)\right) \quad (4)$$

$T_r$ = Real duration during the detection which is the unit of sec.
$K_3$= Attenuation fixing factor.

$$K3 = \frac{\varepsilon(\mu,\mathrm{E})}{\varepsilon(\mu\,\mathrm{ref,E})} \quad (5)$$

μ= Linear absorption coefficient
$K_4$, is a factor of random collosion

$$K4 = \exp(-2 * R * \tau) \quad (6)$$




$K_5$= Collosion fixing factor of consecutively photon emitting from radionuclides[22].

**Figure 2.1**. Map of the rock and sand samples which have been collected for study

## 3. Analysis and results

In this section, radiometric analyses have been applied for understanding of transportation mechanism and origins of the coast sediments. This study has collected some data which are;

- Determination of the radionuclides radioactivity concentration in Fethiye gulf.
- Observation of coast sediments' geological origins.
- Creating of $^{137}$Cs concentration determination along the coast side of Fethiye and aim of reference data base for environmental changes are determined. According to these aims;

- Natural and anthropogenic radionuclides concentrations of sediments which represent surface sediment samples in gulf have been detected.
- Rocks sampling have been done and radioactivity in materials has been calculated.
- HPGe detector has been used for calculation of radioactivity of both sand and rock samples in this study. Relative efficiency of detector is %25 and components are Ortec Model-671 spectroscopy amplifier and Canberra PC MCA Wilkinson ADC. Shielding data modified as 100mm Pb (Lead). HPGe has a sensitivity with the gamma radiation >150 KeV.

### 3.1. Natural and anthropogenic radionuclides activity concentration in Fethiye gulf

Existence of $^{137}$Cs in marine had based on atmospheric nuclear weapons between the years of 1945 – 1963 [23]. According to report about this case pointed out the accumulation of $^{137}$Cs as 90 % has been declared. After Chernobyl incident, all terrestrial region and marines have been affected in negative way in Asia and Europe [24]. Marines do not comprise uranium and thorium but also can contain potassium and anthropogenic. Characteristic activity key of potassium will be saltiness. Average saltiness in the oceans is around 3.5 %. Table 3.1 showed that 20 coast sediments which have been collected with respect to gamma spectrometry determination.

**Table.3.1** Activity concentration of natural and anthropogenic radionuclides in Fethiye coast sediments

| Sample No | Activity Concentration (Bq/kg) | | | |
|---|---|---|---|---|
| | $^{226}$Ra | $^{232}$Th | $^{40}$K | $^{137}$Cs |
| BS-1 | 10±2 | 4±2 | 41±4 | 0.21±0.03 |
| BS-2 | 6±2 | 4±2 | 40±4 | 0.11±0.03 |
| BS-3 | 9±2 | 3±2 | 36±4 | 0.13±0.01 |
| BS-4 | 5±2 | 3±2 | 43±4 | 0.28±0.03 |
| BS-5 | 16±2 | 9±2 | 90±4 | 0.20±0.02 |
| BS-6 | 7±2 | 3±2 | 37±4 | 0.26±0.02 |
| BS-7 | 6±2 | 5±2 | 49±4 | 0.45±0.04 |
| BS-8 | <2 | <2 | 21±4 | 0.26±0.03 |
| BS-9 | <2 | <2 | 18±4 | 0.27±0.03 |
| BS-10 | 7±2 | 9±2 | 150±4 | 0.79±0.02 |
| BS-11 | 17±2 | 4±2 | 49±4 | 0.45±0.04 |
| BS-12 | 6±2 | 4±2 | 46±4 | 0.19±0.03 |
| BS-13 | <2 | <2 | 37±4 | 0.31±0.03 |
| BS-14 | <2 | 3±2 | 48±4 | 0.22±0.04 |
| BS-15 | 11±2 | 13±2 | 135±4 | 0.14±0.02 |
| BS-16 | <2 | <2 | 11±4 | 0.15±0.03 |
| BS-17 | 16±2 | <2 | 9±4 | 0.18±0.03 |
| BS-18 | <2 | <2 | 10±4 | 0.13±0.03 |
| BS-19 | 24±2 | 4±2 | <4 | 0.52±0.04 |
| BS-20 | 20±2 | <2 | 63±4 | 0.27±0.05 |

### 3.2. Rocks Activity Concentration

Serpentinite, neritic, pelagic rock sediments have been collected and sampled which demonstrate us to understand the geological formation. Serpentinite is a rock which becomes metamorphic transformation of ultramafic rock formation from the mantle of earth. By cooling duration and located depths of magma has been increased mineral size of rocks. Table 3.2 has shown activity concentration of rock samples. When table 3.2 has been scientifically examined, radioactivity concentration of rocks will be resulted as $^{226}$Ra, (<1-26.79) Bqkg$^{-1}$, $^{232}$Th(<1- 5.07) Bqkg$^{-1}$ and $^{40}$K(<2-157.48 ) Bqkg$^{-1}$. Data about rocks activity demonstrated there is no big difference between activity of rocks and sand samples. Gamma radiation mostly has been emitted by $^{214}$Pb and $^{214}$Bi for radiometric uranium determination.

These radionuclides have been originated by decaying of radium which has the long half-life ($t_{1/2}$= 1600 years). However, by decaying products have become into radioactive equilibrium, duration which was needed have been controlled by $^{222}$Rn (t1/2= 3.85 day)[25]. Radionuclides between the $^{222}$Rn with $^{210}$Pb have short half-life such as $^{218}$Po; t1/2 = 3.05 min, $^{214}$Pb; t1/2 = 26.8 min, $^{214}$Bi; t1/2 = 19.8 min, $^{214}$Po; t1/2 = 1.6x10$^{-4}$ sec. Table 3.2.a propounds the other researches upon natural activity of sand samples compared with this paper's data.

**Table.3.2.** Activity concentrations of rocks

| Sample No | Activity Concentration (Bg/kg) | | |
|---|---|---|---|
| | $^{226}$Ra | $^{232}$Th | $^{40}$K |
| **K-1** | <1 | <1 | <2 |
| **K-2** | 2.01±0.50 | <1 | 2.32±0.50 |
| **K-2(2)** | 4.43±0.50 | 2.56±0.50 | 45.50±4.49 |
| **K-3** | 3.85±0.50 | 4.72±0.50 | 95.56±9.96 |
| **K-4** | 4.75±0.50 | 5.07±0.50 | 157.48±15.36 |
| **K-5** | 26.79±2.50 | <1 | 11.05±1.98 |

**Table 3.2.a.** Comparison of previous researches and new research upon sand samples

| Research Places | Natural Radionuclides Activity (Bq/kg) | | |
|---|---|---|---|
| | $^{238}$U/$^{226}$Ra | $^{232}$Th | $^{40}$K |
| Orissa Beach / India Sengupta and Saha, 2009 | 15 -560 | 40- 5740 | <MDA-1420 |
| Orissa Beach 2 / India Sengupta and Saha, 2009 | <MDA – 565 | 30- 5530 | <MDA-1850 |
| Songkhla / Thailand Kessaratikoon et al. 2015 | 30.50 | 23.31 | 868.51 |
| Akkuyu / Mersin Kurt and Berker, 2014 | 15.82-39.48 | 3.96-17.18 | 133.54-287.06 |
| Patara / Turkey Radenkovic et al.2008 | 10.8 | 2.56 | 54.5 |
| Manhattan Beach / L.A CA / USA Radenkovic et al. 2008 | 5.0 | 17.3 | 457 |
| Ulcinj / Montanegro Radenkovic et al. 2008 | 7.4 - 15.9 | 9.0 - 17.2 | 192-412 |
| Kalpakham / India Kannan et al. 2002 | 36- 258 | 352-3872 | 324-405 |
| Southeastern Brazil Freitas and Alencar 2004 | 6-180 | 12-349 | 47-527 |
| Tamilnadu / India Suresh - Gandhi et al. 2013 | 35.12 | 713.6 | 349.6 |
| Sithonia / Greece Papadopoulos et al. 2015 | 5-767 | 5-1750 | 185-875 |
| UNSCEAR, 2000 | 35 | 30 | 420 |
| (20 Beaches) New Research Results | 2-24 | 2-13 | 4-150 |

## 4. Conclusion

Average activity concentration of $^{238}$U,$^{226}$Ra, $^{232}$Th ve $^{40}$K and 35 Bq kg$^{-1}$, 35 Bq kg$^{-1}$, 30 Bq kg$^{-1}$ ve 420 Bq kg$^{-1}$, and typical intervals have been explained as; $^{238}$U is 16-110 Bq kg$^{-1}$, $^{226}$Ra is 17-60 Bq kg$^{-1}$, $^{232}$Th is 11-64 Bq kg$^{-1}$ and $^{40}$K 140-850 Bq kg$^{-1}$[26].

When the activity concentration have been compared the UNSCEAR 2000 report, $^{226}$Ra concentrations in this study have been calculated among < 2 - 24±2 Bq/kg ; $^{232}$Th concentrations have been determined as < 2 - 13±2 Bq/Kg; $^{40}$K concentrations have been lined up between <4 - 150±4 Bq/Kg. Rock samples concentration have been resulted between <1 - 157.48 Bq/Kg. These concentrations of radionuclides in Fethiye have been detected as lower than the average activity concentrations. According to these results, not only coast deposit's geological story have been determined but also radioactivity concentration of beach sands and management of coast which was sustainable have been emanated. Fethiye gulf have been identified as safe for public.

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