Analysis of natural radioactivity in Yatağan coal – fired power plant in Turkey

Aydan Altıkulaç[1], *Şeref* Turhan[2] and *Hasan* Gümüş[3]

[1]Muğla Sıtkı Koçman University, Ula Ali Koçman MYO, Department of Electricity and Energy, Muğla, Turkey
[2]Kastamonu University, Faculty of Sciences and Art, Department of Physics, Kastamonu, Turkey
[3]Ondokuzmayıs University, Faculty of Sciences and Art, Department of Physics, Samsun, Turkey

Abstract. Use of the coal in order to generate electricity increases the exposure of people to radiation. In this paper, the activity concentrations of nuclides ^{226}Ra, ^{232}Th and ^{40}K in samples of coal and bottom ash from the Yatagan Coal–Fired thermal power plant determined using gamma ray spectrometer with a NaI(Tl) scintillation detector. The mean activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in the coal were found to be 37.2±2.8 Bqkg^{-1}, 51.8±3.4 Bqkg^{-1} and 166.7±11.1 Bqkg^{-1}, respectively. Whereas in the bottom ashes, the concentrations of the corresponding radionuclides were found to be 62.2±5.6 Bqkg^{-1}, 87.4±5.9 Bqkg^{-1} and 221.0 ±12.5 Bqkg^{-1}, respectively. The findings show that bottom ashes show higher activity concentrations of related radionuclide to coal samples. The absorbed gamma dose rate in outdoor air DR$_{OUT}$ and annual effective dose rate (AED) from coal were calculated to define radıologıcal rısk. The average findings of annual effective doses were detected as 68.6±5.1 μSvy^{-1} and 110.3±11.2 μSvy^{-1}, respectively.

1 Introduction

Energy is one of the most important inputs to the economic and social development of a country. Much of the energy needed in the world is met by fossil sources such as coal and natural gas. The most important share of fossil energy resources in Turkey belongs to the coal mine. According to World Energy Council statistics, world coal reserves freeze to 861 billion ton [1]. About 1.7% of the world's coal reserves are in Turkey. Coal is used as fuel in coal operated power plants to generated electricity in Turkey. Coal and lignite fueled thermal power plants in Turkey reported total electricity generation of 90.335 GWh per year. In the composition of fuels such as coal, there are fewer or more natural radioactive substances, such as ^{226}Ra, ^{210}Po and ^{210}Pb, as well as ^{40}K, derived from ^{238}U and ^{232}Th. The uranium and other radioisotopes in the lignite coal burned at high temperatures in thermal power plants becomes enrich and passes to the ash. Part of the heavy ash falls down to the bottom of the furnace as "bottom ash" together with unburned organic matter, while light ashes are transported along with hot gases to the pail and form fly ash. The average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in coal according to UNSCEAR are 20, 20 and 50 Bqkg^{-1}, respectively [2-4]. The fly ash formed by burning the coal causes the radioactive materials to spread in the atmosphere. A large proportion of the radioactivity is remains in the bottom ash after combustion. About 0.5-2 % of the total ash resulting from the fly ash combustion is released to the atmosphere and this event creates a potential risk for the very close environment of the coal fired power plant [5]. The amount of coal required to produce 1 GWh of electricity per year is $3×10^9$ kg. As a result, the radioactive pollution given to the atmosphere per year is 4000 MBq for ^{40}K, 1500 MBq for ^{238}U through ^{226}Ra, 5000 MBq for ^{210}Pb and ^{210}Po and 1500 MBq for the radionuclides of ^{232}Th decay series, from ^{232}Th to ^{224}Ra. As well as there are the ash mountains that generate atmospheres ^{222}Rn around each coal –fired power plant. Especially radioactive radon (^{222}Rn) gas and short-lived decay products (^{214}Bi of ^{214}Pb etc.) can be taken into the body through the respiratory tract and increase the risk of cancer by damaging the lung tissue [6]. In this study, the activities of natural radioactive elements were determined in the samples of coal and bottom ash.

2 Material and method

2.1 Preparing samples for measurement

Yatağan Thermal Power Plant has 3x210 MW power is located in Muğla, which has a significant portion of Turkey's lignite reserves [7]. In this paper, radioactivity measurements were made in the samples of bottom ash generated by burning of coal and coal used as fuel in Yatağan Thermal Power Plant. All samples were dried for one day in the oven at a preheated of 100 degrees. The dried samples were put in standard vessels and the mass and date of creation were recorded. Each sample vessel was wrapped with parafilm to provide a seal.^{226}Ra

and ^{232}Th in all samples were expected to reach a radioactive equilibrium for a month.

2.2 Gamma measurements

Gamma spectrometric measurements of ^{226}Ra, ^{232}Th and ^{40}K in the samples were carried out by the agency of scintillation gamma-ray spectrometer with a sodium iodide (NaI) detector. The calibration of the detector performed using photo peaks from radioactive standards IAEA- RGU-1, IAEA-RGTh-1 and IAEA-RGK-1 reference materials. The detector has an energy resolution of 46 keV at 622 keV ^{137}Cs. The ^{226}Ra activity of the samples was detected by means of the density of 351.9 keV and 609.3 keV gamma lines of ^{214}Pb and ^{214}Bi, respectively. ^{232}Th activity was acquired through the gamma publisher of ^{228}Ac at 911.21 keV. ^{40}K concentration was directly read from spectrum analysis results. Spectrum analyzes were carried out using the ScintiVision gamma ray software.

3. Result and discussion

3.1 Activity concentration

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were calculated for 20 different coal and 20 different bottom ash sample. The results for coal samples are shown in Table 1. As seen in Table 1, the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were measured as 37.2±2.8 Bqkg^{-1}, (range from 26 to 47), 51.8±3.4 Bqkg^{-1}, (range from 19 to 80) and 166.7±11.1 Bqkg^{-1} (range from 137 to 189), respectively. The measured radioactivity and related radiological parameters in the bottom ash are as in Table 2. So, it can be said that bottom ashes show higher activity concentrations of related radionuclide to coal samples. The data obtained is higher than the data in UNSCEAR report [2,3].

3.2 Equivalent radium activity

This parameter is calculated by multiplying the corresponding radioactive elements by different coefficients and this calculation is shown in the following Equation [8,9].

$$Ra_{eq} = A_{Ra} + \frac{10}{7} A_{Th} + \frac{10}{130} A_K \qquad (1)$$

Where A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively. As seen in Table 1 and Table 2, the equivalent activities calculated for bottom ash are about twice that of coal. Where A_{Ra}, A_{Th} and A_K are the activities of ^{226}Ra, ^{232}Th and ^{40}K, respectively.

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Table 1. Activity concentrations and calculated gamma doses in coal samples

Sample ID	^{226}Ra (Bqkg^{-1})	^{232}Th Bqkg^{-1})	^{40}K (Bqkg^{-1})	Ra$_{eq}$ (Bqkg^{-1})	External absorbed gamma dose D$_R$ (nGyh^{-1})
C2	29±2	19±1	178±11	68 ±6	32±2
C3	49±4	40±3	168±10	118±9	54±4
C4	37±2	23±1	186±12	83±6	39±3
C5	36±2	48±3	162±10	115±8	53±4
C6	40±3	52±3	189±13	128±9	58±4
C7	45±4	57±4	169±11	138±10	63±5
C8	39±3	53±3	137±10	124±9	56±4
C9	36±3	46±3	144±10	111±9	51±4
C10	47±3	60±4	180±12	145±11	66±5
C11	32±2	45±3	168±11	108±8	49±3
C12	36±3	48±3	156±11	115±8	53±4
C13	38±2	51±3	173±11	125±9	56±4
C14	40±3	54±3	188±12	130±10	59±4
C15	35±2	69±4	154±10	144±12	65±5
C16	39±2	77±5	172±11	160±13	73±5
C17	40±3	75±4	171±11	158±12	72±5
C18	40±4	80±4	137±9	163±12	74±6
C19	26±2	49±3	180±12	97±8	50±3
C20	33±2	54±3	153±10	120±9	51.±4
Average	**37±2**	**51±3**	**166±11**	**121±9**	**56±4**

3.3 Calculation of gamma doses

The gamma dose taken in the air (D$_R$) at a height of 1 m from the ^{226}Ra, ^{232}Th, and ^{40}K found in the structure of the material was calculated by the following Equation [10].

$$D(nGyh^{-1}) = 0.462A_{Ra} + 0.623A_{Th} + 0.0414A_K \qquad (2)$$

where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K in Bqkg^{-1}, respectively. External absorbed gamma dose rate calculated for coal and bottom ash samples are shown in Table 1 and Table 2. The calculated average value for coal is 56.9±4.4 nGyh^{-1} while the calculated value for bottom ash is 90.8±6.5 nGyh^{-1}. The dose rate in airdoors from terrestrial gamma rays in normally is around 60 nGyh^{-1}, with the mean range from 10 to 200 nGyh^{-1}, according to the UNSCEAR 2000 report [11].

The calculated results for coal and bottom ash samples are 68.6±5.1 and 110.3±11.2 µSvy^{-1}, respectively. According to the UNSCEAR 2000 report, this value was announced as 70 µSvy^{-1} for the world average [11]. It can be said that the mean value calculated for coal is around the world average. But the mean value for bottom ash is above the world average.

Table 2. Activity concentrations and calculated gamma doses in bottom ash samples.

Sample ID	^{226}Ra (Bqkg-^{1})	^{232}Th (Bqkg-^{1})	^{40}K (Bqkg-^{1})	Ra$_{eq}$ (Bqkg-^{1})	External absorbed gamma dose D$_R$ (nGyh-^{1})
BA1	47±3	34±2	241±14	112±6	53±3
BA2	48±3	50±3	239±14	136±8	62±4
BA3	60±5	49±3	250±14	148±8	74±4
BA4	64±6	76±5	267±15	191±11	87±5
BA5	74±6	99±6	220±12	230±12	103±7
BA6	65±5	84±6	204±12	200±11	89±6
BA7	63±5	86±6	172±9	197±11	88±6
BA8	68±5	92±6	203±11	213±12	95±6
BA9	60±5	80±5	176±10	187±10	83±5
BA10	59±4	77±5	191±11	183±10	81±5
BA11	59±4	79±5	202±11	186±10	84±6
BA12	72±6	98±6	194±10	226±13	100±7
BA13	70±6	93±6	227±13	219±12	98±7
BA14	59±4	76±5	253±14	185±11	83±5
BA15	71±6	132±8	237±13	276±13	122±8
BA16	58±3	112±7	256±14	249±14	105±7
BA17	50±3	96±6	219±12	202±12	90±6
BA18	55±3	115±7	234±13	235±13	104±7
BA19	62±5	104±6	216±12	225±12	100±7
BA20	74±6	117±7	227±12	256±14	114±8
Average	62±5	87±5	221±12	200±11	90±6

4 Conclusions

Muğla is located in Turkey, where has a significant portion of lignite reserves, and, ^{226}Ra, ^{232}Th, and ^{40}K radioisotopes are naturally found in these lignite coals by various measurements. The purpose of this study is to make measurements of natural radioactivity in samples of coal and bottom as samples taken from Yatağan Coal-Fired Power Plant basin in Muğla. The results show that the natural radioactivity of the bottom ash is about 2 times that of the coal natural radioactivity and this is an expected result. It can be said that the concentrations of radium, thorium and potassium in coal and bottom ash samples are slightly above the world average in the finds obtained.

References

1. World Energy Concil, Survey of Energy Resources, London. (2010)
2. UNSCEAR Ionizing Radiaiton: Sources and biological effects. United Nations Scientific Commitee on the Effects of Atomic Radiaiton, United Naitons, New York. (1982)
3. UNSCEAR Ionizing Radiaiton:Sources and biological effects. United Nations Scientific Commitee on the Effects of Atomic Radiaiton, United Naitons, New York. (1988)
4. Gür. F, and Günseli. Y, Journal of Environmental Science and Health, Part A. **45**, 1900-1908 (2010)
5. Bem, H., Wieczorrkowski, P., Budzanowski, M, J. Environ. Radioact. **61**, 191-201 (2002)
6. Aycik, G.A, and Ercan, A, J. Environ. Radioact. **35**, 23-35 (1997)
7. Akyüz. T, Akyüz. S, Varinlioğlu. A, Köse. A, Eric. J, Davies. D, Spectroscopy Letters. **29**, 1131-1139 (1996)
8. Turhan. Ş, Arıkan. I.H, Yücel. B, Varinlioğlu. A., Köse. A, Fuel. **89**, 2528-2535 (2010)
9. Beretka. J, Mathew. P.J, Health Phys, **48**, 87-95 (1985)
10. Kurnaz. A, Gezelge. M, Hançerlioğulları. A, Çetiner. M.A, Turhan. Ş, Human and Ecological Risk Assessment: An International Journal. **22**, 1375-1385 (2016)
11. UNSCEAR (2000) Ionizing Radiaiton: Sources and biological effects. United Nations Scientific Commitee on the Effects of Atomic Radiaiton, United Naitons, New York.