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Full Length Research Paper

Natural radioactivity of coals and its risk assessment

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Burning of the coal that occur around coal-fired power plants and also in many of the habitance during the winter season may affect human health as it contains natural radionuclides. In this study, the radioactivity of the different types of coal samples used in Turkey has been determined using a γ-ray spectrometer which consists of a NaI (Tl) detector connected MCA, and possible health effect were estimated. The activity of ^{238}U, ^{232}Th, and ^{40}K radionuclids in coals have ranged from 35.95 to 110.37, 15.63 to 22.56, and from 135.59 to 321.90 Bq/kg respectively. To estimate health effect due to the activity of those radionuclids, the radium equivalent (Ra_{eq}), external hazard index (H_{ex}), absorbed dose (D) and effective dose rate (EDR) have been obtained. The results of this study can provide valuable information for risk assessment of the utilization of coal.

Key words: Coal, radioactivity, NaI(Tl), radiation dose, radiation hazards.

INTRODUCTION

The natural radionuclides in coals release to the atmosphere gives rise to one of the components of technological natural radiation. Burning of the coal produces coal fly ash that can also be release into environment containing well known radionuclides including uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K). The coals are a major source for power and fuel in Turkish household. Considering the reality of using coal in most of the places as the warming materials especially for winter season in Turkey, its radioactivity level would be measured and the radiation hazards should be assumed in order to provide an appropriate protection for humans. Thus the main goal of this study is to measure the radioactivity of widely used coal samples in Turkey and evaluate its effect on human health. For this purpose, coal samples were collected and the activity of ^{226}Ra, ^{232}Th and ^{40}K content have been measured using γ-ray spectroscopy and the radium equivalent (Ra_{eq}), external hazard index (H_{ex}), absorbed dose (D) and effective dose rate (EDR) have been obtained to estimate health effect of those coals.

MATERIAL AND METHODS

Sample collection and preparation

A total of 4 different coal samples were collected from suppliers and/or factories and natural radioactivity for ^{238}U, ^{232}Th and ^{40}K radionuclids have been measured. The samples were sieved and dried for 24 h at 110°C temperature. A cup filled by sample and sealed tightly with a thick tape around its neck to limit any gas escape from it, and stored for four weeks to get secular equilibrium to be achieved between ^{226}Ra and its progeny (Yang et al., 2005.).

Activity measurements

The natural activity of coal was measured using a γ -ray spectrometer system as described elsewhere (Akkurt et al.). The spectrometer consists of a NaI(Tl) 3" X 3" Canberra detector, preamplifier (2007 P), NIM High-Voltage unit (Canberra 3102D), NIM amplifier (Canberra, 2022) and Multi-Channler-Analyser (MCA). The around of the sample cup was shielded by 3 cm lead in order to shield from other sources. The schematic view of the experimental setup is shown in Figure 1. The energy calibration of the detection system was done using radioactive sources of ^{137}Cs and ^{60}Co which emit 662 and 1170, 1332 keV respectively. The calibration γ-ray energy spectrum for ^{60}Co source and related fit obtained from those sources for the detector system is displayed in Figure 2 and 3 respectively. After calibration of the detection sys-tem, the background and real measurement have been done for 2000 s duration.

A typical γ -ray spectrum for coal sample is shown in Figure 4 where the peaks related to the interested radionuclids (^{238}U, ^{232}Th and ^{40}K) are clearly seen. The measurement was based on recording natural radioactivity quantities of three natural long-live elements: ^{238}U, ^{232}Th and ^{40}K which are considered the photopeaks at 1760, 2610, 1461 keV respectively, in the natural γ-ray spectrum. In Table 1 the γ -ray energy and emission rate for those of nuclids are tabulated (Baloguna et al., 2003).

The activities for the natural radionuclides from the measured samples were calculated using the following relation:

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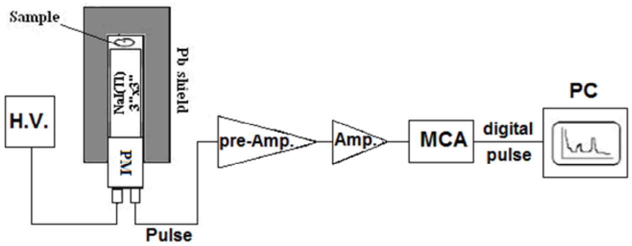

Figure 1. Schematic view of experimental setup.

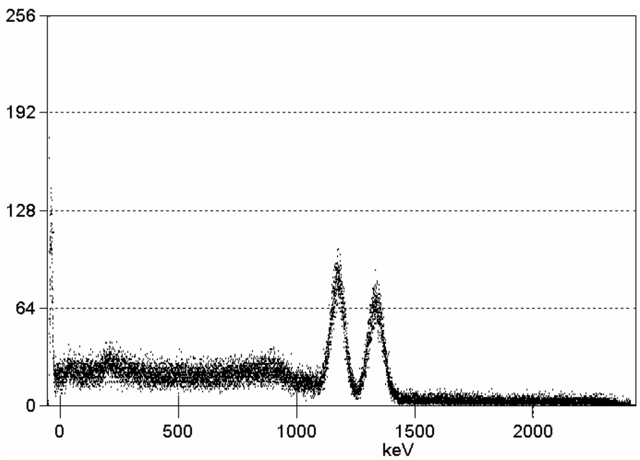

Figure 2. A calibration spectrum obtained for ^{60}Co source.

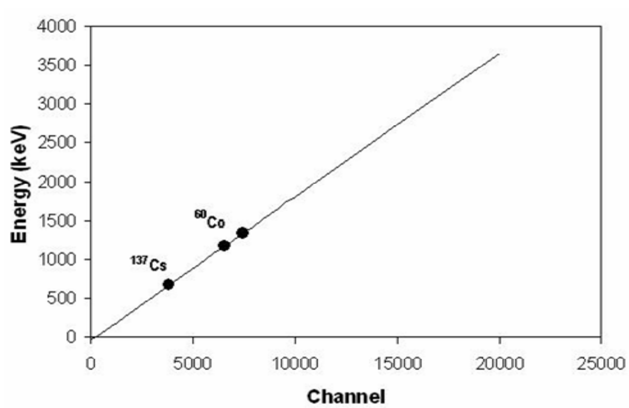

Figure 3. Calibration fit of the detector.

$$A(Bq/kg) = \frac{N}{\varepsilon \cdot P \cdot M \cdot t} \quad (1)$$

Where N is the net background subtracted counts recorded in the detector, ε is the detector efficiency of the specific γ-ray, P is the absolute transition probability of □-decay (Table 2), M is the mass of the sample (kg) and t is the counting time.

RESULTS AND DISCUSSIONS

The natural activity of coals has been measured and the results have been tabulated in Table 2. It can be seen from this table that the measured radioactivities have ranged from 35.95 to 110.37 Bq/kg for ^{238}U, from 15.63 to 22.56 Bq/kg for ^{232}Th, and from 135.59 to 321.90 Bq/kg for ^{40}K. The results of activity have also been displayed in Figure 5 where it can be seen that the highest value obtained for ^{40}K and the lowest value obtained for ^{232}Th from all samples. It is also clear that the activity of ^{40}K and ^{232}Th obtained from sample 2 are higher than other samples while activity of ^{238}U obtained from sample 1 is higher than the others.

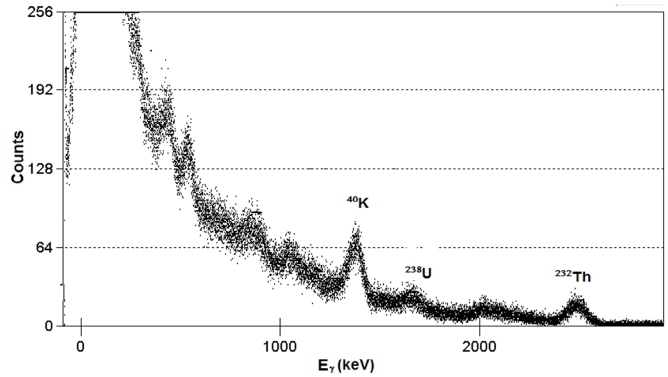

Figure 4. A typical γ -ray spectrum obtained for sample 1.

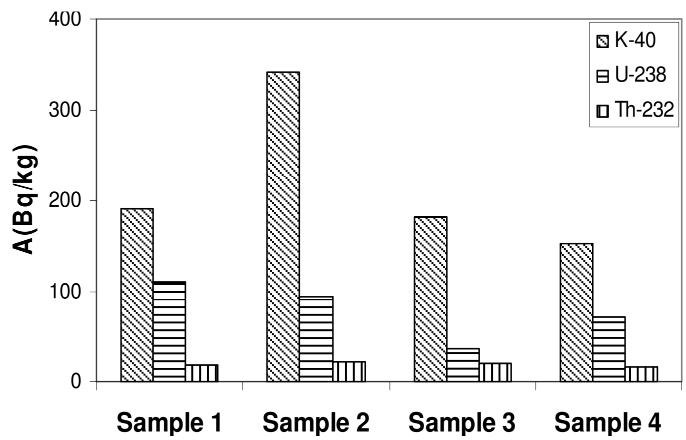

Figure 5. Natural radioactivity of the coals.

In order to assess the radiological hazard due to the coals both radium equivalent activity (Ra_{eq}) in Bq/kg and external Hazard Index (H_{ex}) have been obtained.

The Ra_{eq} represents the uniformity with respect to exposure to radiation as the distribution of ^{226}Ra, ^{232}Th and ^{40}K in materials is not uniform. Ra_{eq} is calculated through the following equation as described in ref. (Beretka et al., 1985; Yang et al., 2005.):

$$Ra_{eq} = A_{Ra} + 1.43 A_{Th} + 0.07 A_K \quad (2)$$

Where A_{Ra}, A_{Th}, A_K are the activity of ^{226}Ra, ^{232}Th and ^{40}K

Table 1. γ-ray energies and emission rate for ^{238}U, ^{232}Th and ^{40}K radionuclids (Baloguna et al., 2003).

Element	Nuclide	Half life	γ-ray energy (keV)	Emission rate
^{238}U	^{214}Pb	26.8 min	295.2, 351.2	19, 38.9
	^{214}Bi	19.9 min	609.3, 1764.7	43.3, 17
	^{208}Tl	3.05 min	583.2, 2614.7	185.77, 99.79
^{232}Th	^{228}Ac	6.13 h	911.1	27.7
^{40}K		1.3 10^9 yr	1460.8	10.7

Table 2. Results for coal samples.

Sample name	Sample code	Activity (Bq/kg)			Raeq	Hex	D	EDR
		^{238}U	^{232}Th	^{40}K			(nGy/h)	(mSv/y)
İthal Kömür	Sample 1	110,37	18,40	191,45	150,0906	0,409162	70,09119	0,08596
Kısrak Deresi	Sample 2	94,05	22,56	321,90	150,2037	0,412256	71,31059	0,087455
Tunçbilek	Sample 3	35,95	20,44	164,41	77,93555	0,213968	36,55406	0,04483
Biriket Kömür	Sample 4	71,569	15,63	135,59	104,5616	0,285389	48,84784	0,059907

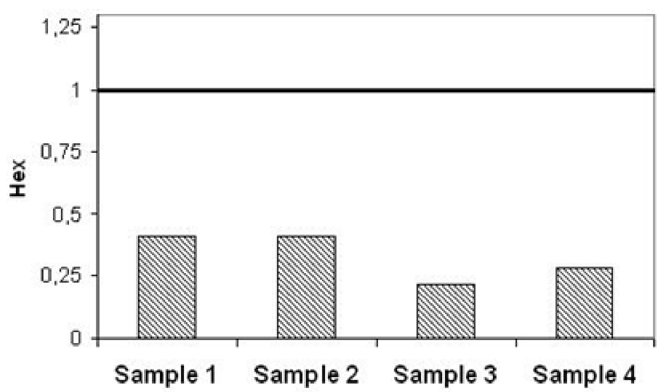

Figure 6. Hazard Index for all samples and comparison with the limit value of the unity.

in Bq/kg, respectively. While defining Ra_{eq}, it has been assumed that 370 Bq/kg of ^{226}Ra or 259 Bq/kg of ^{232}Th or 4810 Bq/kg of ^{40}K produces the same gamma dose rate. The obtained results for Ra_{eq} is shown in Table 2 where it can be seen that none of the Ra_{eq} values for the coal samples exceeded the suggested maximal admissible value of 370 Bq/kg (OECD, 1979). Therefore, people who use those coals do not have a high risk of being exposed to radioactivity. The H_{ex} is calculated using following equation (Yu et al., 1992):

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \quad (3)$$

Where the A_{Ra}, A_{Th}, A_K have the same meaning in equation 2. The value of H_{ex} must be less than unity which corresponds to the upper limit of Ra_{eq} (370 Bq /kg), in order to keep the radiation hazard under upper limit. The results have been tabulated in Table 2 where it can be seen that the highest value obtained for sample 2. The results have also been displayed in Figure 6 where it is clear that all measured results are much lower than upper limit of the unity.

To provide a characteristic of the external terrestrial □-ray, the absorbed dose rate (D) in air at about 1 m above the ground is calculated using the equation below (Veiga et al., 2006; UNSCEAR, 2000):

$$D(nGy \cdot h^{-1}) = 0.462 A_{Ra} + 0.604 A_{Th} + 0.0417 A_K \quad (4)$$

Where A_{Ra}, A_{Th}, A_K have the same meaning in equation 2. The absorbed dose rate ranged from 36.55406 to 71.31059 nGy/h as shown in Table 2. As the global average value of absorbed dose rate is 55 nGy/h (UNSCEAR, 2000), two of the samples values are higher than this average value. In order to judge the health effects of the absorbed dose, annual effective dose rates (EDR) should be obtained. From the conversion coefficient from the absorbed dose in air to the effective dose (0.7 Sv/Gy) and the outdoor occupancy factor (0.2) proposed in ref. (Veiga et al., 2006), EDR has been obtained from the following formula (Cevik et al., 2007):

$$EDR(mSv \cdot y^{-1}) = D(nGy \cdot h^{-1}) \times 8760(h \cdot y^{-1}) \times 0.2 \times 0.7(SvGy^{-1}) \times 10^{-6} \quad (5)$$

The EDR due to used coal have been obtained from 0.04483 to 0.08745 mSv.y^{-1}.

All the results are shown in Table 2 and displayed in Figure 7 where the results were compared with the UNSCEAR limit, where the average EDR from the terrestrial radionuclids is 0.460 mSv y^{-1} in areas with the

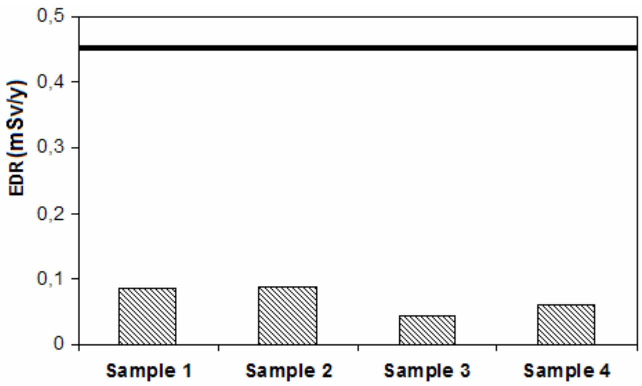

Figure 7. Effective dose rate for all samples and line shows world average value.

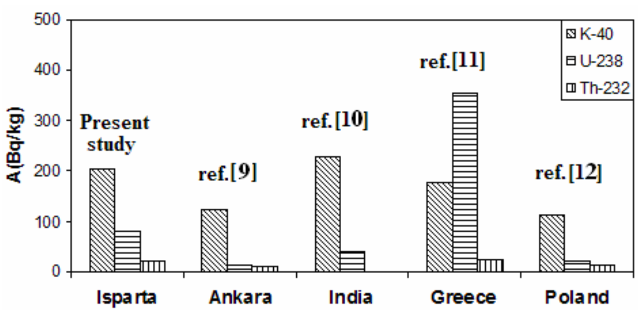

Figure 8. Measured activity results and comparison with the measurement done in other places (Cevik et al., 2007; Bem et al., 2002; Karangelos et al., 2004; Mishra UC. 2004).

normal background radiation (UNSCEAR, 2000). It can be clearly seen from this figure that all the obtained EDR values are lower than the limit (solid line in Figure 7).

Finally it is interesting to compare results obtained from this work with some other results from both in Turkey and other countries (Bem et al., 2002; Karangelos et al., 2004; Mishra, 2004.) and all are displayed in Figure 8.

Conclusion

It can be seen from all measured and extracted results from these measurements that all values are under the recommended limits. As a result of this, it can be concluded that people who are using those of coals are safe in terms of radiation hazards.

REFERENCES

Akkurt I, Akyildirim H, Mavi B, Kilincarslan S, Basyigit C (in press). Radiation shielding measurement of the concrete containing zeolite. Rad. Meas.

Baloguna FA, Mokobia CE, Fasasi MK, Ogundare FO, (2003). Natural radioactivity associated with bituminous coal mining in Nigeria. Nucl. Instr. and Meth. in Phys. Res. A 505: 444–448.

Bem H, Wieczorkowski P, Budzanowski M (2002). Evaluation of technologically enhanced natural radiation near the coal-fired power plants in the Lodz region of Poland” J. Environ. Radioact. 61-191.

Beretka J, Mathew PJ (1985). Natural radioactivity of Australian building materials, industrial wastes and by-products Health Phys. 48: 87- 95

Cevik U, Damla N, Nezir S, 2007. Radiological characterization of Cayırhan coal-fired power plant in Turkey” Fuel. 86: 2509- 2513.

Karangelos DJ, Petropoulos NP, Anagnostakis MJ, Hinis EP, Simopoulos SE (2004). Radiological characteristic and investigation of the radioactive equilibrium in the ashes produced in lignite-fired power plants. J. Environ. Radioact. 77-233.

Mishra UC (2004). Environmental impact of coal industry and thermal power plants in India. J. Environ. Radioact. 72-35.

OECD 1979 (Organization for Economic Cooperation and Development), Exposure to radiation from the natural radioactivity in building materials. Report by a Group of Experts of the OECD Nuclear Energy Agency, OECD,Paris, France.

UNSCEAR 2000, (United Nations Scientific Committee on the Effects of Atomic Radiation), Exposure from natural sources of radiation, U.N. New York .

Veiga R, Sanches N, Anjos RM, Macario K, Bastos J, Iguatemy M, Aguiar JG, Santos AMA, Mosquera B, Carvalho C, Baptista Filho M, Umisedo NK (2006). Radiat. Meas. 41: 189-196.

Yang YX, Wu XM, Jiang ZY, Wang WX, Lu JG, Lin J (2005). Radioactivity concentrations in soils of the Xiazhuang granite area, China. Appl. Radiat. Isotopes 63: 255-259.

Yu KN, Guan ZJ, Stokes MJ, Young ECM (1992). The assessment of natural radiation dose committed to the Hong Kong people. J. Environ. Radioact 17-31.