Vertical distribution of ^{210}Pb around a uraniferous coal-fired power plant in Western Turkey

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Abstract

In the present study the spatial and the vertical distributions of ^{210}Pb were investigated in the soils around a uranifereous coal fired power plant in Yatagan Basin, in Western Turkey. The variation of ^{226}Ra activity along the soil profiles was studied to assess the unsupported ^{210}Pb distribution in the same samples.

^{226}Ra was measured by gamma spectroscopy and ^{210}Pb activities were determined from ^{210}Po activities using radiochemical deposition and alpha spectroscopy.

The total ^{210}Pb activity concentrations in bulk core samples varied in the range of 38Bq kg^{-1} -250 Bq kg^{-1} in the study sites and of 22 Bq kg^{-1} - 78 Bq kg^{-1} in reference site. In the sectioned cores sampled from the study areas the ranges for activity concentrations of ^{226}Ra, total ^{210}Pb and unsupported ^{210}Pb are 24 Bq kg^{-1} - 77 Bq kg^{-1}; 39 Bq kg^{-1}-344 Bq kg^{-1} and 4 Bq kg^{-1}-313 Bq kg^{-1} respectively. Corresponding ranges for reference site are 37Bq kg^{-1}-39Bq kg^{-1}; 39 Bq kg^{-1}-122 Bq kg^{-1} and 1 Bq kg^{-1}-83 Bq kg^{-1}.

Keywords: Total ^{210}Pb, Unsupported ^{210}Pb, CPPs.

1. Introduction

Energy production from coal is one of the major sources of increased natural radioactivity in the atmosphere. Coal contains natural radionuclides and their daughter products in trace quantities. The amounts of natural radionuclides discharged to the atmosphere from a power plant depend on a number of factors such as the concentrations in coal, the ash content, the temperature of the combustion, the partitioning between bottom ash and fly ash and the efficiency of the emission control device. Despite stack filtration and other trapping methods, soils in the environment of coal-fired power plants are often found to be enriched in such ash-borne particles (Flues et al., 2002; Ugur et al., 2003a).

^{210}Pb ($t_{1/2}$=22.26 years) is a naturally occuring radionuclide, product of the ^{238}U decay series, derived via a series of other short-lived radionuclides from the decay of gaseous ^{222}Rn ($t_{1/2}$=3.8 days), the daughter of ^{226}Ra ($t_{1/2}$=1622 years). ^{210}Pb is derived naturally from the lithogenic minerals in subsoil and also from the atmosphere as a result of combustion of fossil fuel (Fujiyoshi, 2004). ^{210}Pb content of soil produced by the natural in situ decay of ^{226}Ra is termed 'supported' ^{210}Pb because it is in equilibrium with its parent. On the other hand, upward diffusion of a small portion of the ^{222}Rn produced naturally in soils and rocks releases ^{222}Rn to the atmosphere and the subsequent fallout of ^{210}Pb provides an input to surface soils which is not in equilibrium with ^{226}Ra. ^{210}Pb activity in excess of the fraction which is derived from decay of the in situ ^{226}Ra is called 'unsupported' ^{210}Pb. The amount of unsupported or atmospherically derived ^{210}Pb in soil can be calculated by measuring both the ^{210}Pb and ^{226}Ra activities and subtracting the ^{226}Ra-supported ^{210}Pb component from the total ^{210}Pb in the sample (Walling et al., 2003).

Deposition of fallout ^{210}Pb from the atmosphere has been relatively constant throughout the time because of its natural origin. Existence of additional sources of natural radionuclides in the environment increases ^{210}Pb input into atmosphere. Atmospheric fluxes of fallout ^{210}Pb have been documented for many parts of the world, either through analysis of ^{210}Pb in rainfall or analysis of unsupported ^{210}Pb in stable, undisturbed soils (Walling et al., 1999).

The goal of this survey is to investigate spatial distribution of ^{210}Pb from the atmosphere in Yatagan Basin where there exist power plants fed with coals rich in uranium (Yener and Uysal, 1996). It is aimed also to assess unsopperted ^{210}Pb via vertical distribution of total ^{210}Pb and ^{226}Ra in the soil profiles to estimate the excess ^{210}Pb input into the basin from the plant.

2. Materials and methods

Location

Yatagan basin is located in Gokova , in Western Turkey, where there exist three major coal-fired power plants fed with uraniferous coal. These are Yatagan, in operation since 1982, Yenikoy, since 1988 and Kemerkoy, since 1994. Yatagan plant has three units producing 210MW each; the other two plants have only two units of similar power.

It is known that natural radionuclide content of the lignites taken out from this region is relatively high. In a report by Yener and Uysal (1996) ^{238}U activity concentrations in coal, bottom ash and fly ash in the samples of these CPPs were given as 314 - 405 Bq kg^{-1}; 981-1307 Bq kg^{-1} and 748-1076 Bq kg^{-1}, respectively.

Four sampling sites not inhabited (Yatagan Hill, 4.5 km, Peynirli Hill, 3 km, Kırtas Hill, 7 km and Urnez Hill, 7 km from the plant) around one of three plants, namely Yatagan CPP, in the present work are shown in Fig 1. A site in a protected area not effected by pollution from the plant was chosen as the reference site.

The climate in the region is typically Mediterranean, with a mean annual rainfall of 630 mm, most of which is concentrated during the period extending from December to April.

Fig 1

To document the spatial distribution of fallout ^{210}Pb concentrations within the field, bulk soil cores were collected at different grid cells using a hand corer sampler with 15.5cm and 8.5cm diameters. The study sites were sampled with varying grid sizes between 10x24 m^2 and 25x64m^2 and proper spacing at each study region depending on the topographic properties of the land. In total, 66 bulk soil cores were collected from the study sites. Information on the vertical distribution of fallout ^{210}Pb and ^{226}Ra activities in the soil profiles was obtained from 82 sectioned soil cores collected from all sites within the fields in order to observe excess ^{210}Pb with respect to the reference profile. Table 1 shows the topographic data of the study sites.

Table 1

Soil Properties of Yatagan Basin

Organic matter content significantly effects ^{238}U and ^{210}Pb activities in the soils (Ugur et al., 2004b, Navas et al., 2002).The main soil type of Yatagan hill rarely covered with shrubs is classified as Lithic Rhodoxeralf which is formed on hard sedimentary calcareous rock. These soils are rich in organic matter like Peynirli and Kırtas soils . The soils of Peynirli and Kırtas hills are classified as Lithic Xerorthent within the dark gray and yellow colour. The Kırtas hill slopes are covered with stony soils whereas the soils of Peynirli hill slopes is covered with uniform vegetation.? Urnez soils are classified as Typic Rendoll within dark gray colour. They have high organic matter and lime content (Ugur et al., 2004b).

^{210}Pb determination in soils

As the determination of the ^{210}Po activity by alpha-counting provided an indirect measurement of the ^{210}Pb activity (precursor of ^{210}Po), ^{210}Pb concentrations were obtained from ^{210}Po activities measured after attaining the radioactive equilibrium. All samples were oven dried at 105°C for 48 h, disaggregated and sieved to separate the <2 mm fraction. Soil samples were stored for a period of 2-3 half-lives of ^{210}Po ($t_{1/2}$=138d) before analysis to allow build-up of ^{210}Po from ^{210}Pb. Spontaneous deposition via radiochemical separation was used for polonium determinations. The chemical method employed in this study is described in detail elsewhere (Ugur et al., 2003b). Measurement of ^{210}Po activity was made through its 5.30 Mev alpha particle emission using ^{208}Po (5.11 Mev alpha emission, $t_{1/2}$ = 2.9 yr) as the internal tracer(AEA) and the silicon surface-barrier detector (Tennelec,400mm^2, 300 μ mm depletion depth). Chemical yields ranged from 77 to87 % by the recovery of ^{208}Po and efficiency of the alpha dedector was 29%.

3. Results

The spatial distributions of total ^{210}Pb concentrations in bulk soils samples are given together with the vertical distributions of ^{210}Pb and ^{226}Ra in four sampling sites and in reference site of Yatagan Basin. Reference area was selected in a site 8 km from the plant. Due to the hills covered with high trees exist between the reference area and the plant, this site is not effected by radioactive emmisions from the plant (Ugur et al., 2003b).

In the reference site the ^{226}Ra concentration along the profiles in sectioned cores is almost constant ranging in 36 Bqkg^{-1} and 39 Bqkg^{-1} .The total ^{210}Pb and the unsupported ^{210}Pb activities are in the range of 99 Bqkg^{-1} -122 Bqkg^{-1} and 1 Bqkg^{-1} -83 Bqkg^{-1} respectively in the same profiles. The total ^{210}Pb activity concentrations in bulk cores in reference site varied from 22 Bqkg^{-1} to 78 Bqkg^{-1}.

At Yatagan Hill, from the the vertical distribution data ,^{226}Ra, total ^{210}Pb and unsupported ^{210}Pb activity concentration ranges are found as 28 Bq kg^{-1}-31 Bq kg^{-1}; 66 Bq kg^{-1}-344 Bq kg^{-1} and 38 Bq kg^{-1}-313 Bq kg^{-1}, respectively. The total ^{210}Pb activity concentrations in bulk core samples varied in the range of 100Bq kg^{-1} -250 Bq kg^{-1} in the study sites. The relatively high excess ^{210}Pb in this area would be attributed to the fact that Yatagan Hill is located 4.5 km from the plant, the land is bare and has long been exposed to pollution from ash deposits that exists at the north of the plant.

The second highest polluted area is Peynirli Hill. The ranges for ^{226}Ra, total ^{210}Pb and unsupported ^{210}Pb in sectioned soil samples are 24 Bq kg^{-1}-31 Bq kg^{-1}; 44 Bq kg^{-1}-172 Bq kg^{-1} and 19 Bq kg^{-1}-141 Bq kg^{-1}, respectively. The total ^{210}Pb activity concentrations in bulk core samples varied in the range of 61 Bq kg^{-1} -122 Bq kg^{-1} in this site. Peynirli Hill is 3 km from the plant and covered with maquis and shurbs.There are ash piles newly formed very close to the study site. The Hill is exposed to ESE wind during most of the year.

At Kırtas Hill, the ranges for total ^{210}Pb and unsupported ^{210}Pb in sectioned soil samples are 72 Bq kg^{-1}-166 Bq kg^{-1} and 11 Bq kg^{-1}-89 Bq kg^{-1}, respectively. The ^{226}Ra activity is constant as 77 Bq kg^{-1} along the profile.The total ^{210}Pb activity concentrations in bulk core samples varied in the range of 55Bq kg^{-1} -194 Bq kg^{-1} in this site. Although the total lead data at this site is relatively high, the unsupported ^{210}Pb is close to the value at reference site. This would be because Kırtas Hill is located 7 km from the plant and the radium concentrations of the soils are higher than those in the soils of the other sites .

At Urnez Hill, the ranges for ^{226}Ra, total ^{210}Pb and unsupported ^{210}Pb in sectioned soil samples are 45 Bq kg^{-1}-54 Bq kg^{-1}; 39 Bq kg^{-1}-144 Bq kg^{-1} and 4 Bq kg^{-1}-96 Bq kg^{-1}, respectively. The total ^{210}Pb activity concentrations in bulk core samples varied in the range of 38Bq kg^{-1} -83 Bq kg^{-1} in this site. Urnez Hill is located far from the plant. The land is suitable for agriculture, so almost all the soils of sampling areas are mixed up by tillage. This likely reduces the ^{210}Pb concentrations on the surface layers (Fig 2).

Fig 2

4. Conclusions

The ^{210}Pb activity concentrations are found to be higher with varying amounts in both bulk and sectioned cores in all sites when compared with reference site data. Unsupported ^{210}Pb activities in the surface layers of the soil profiles at the study sites were also compared with those at reference site. The difference varied between 6 Bqkg^{-1} and 230 Bq kg^{-1} pointing out to the considerable impact of the power plant in the basin especially at Yatagan Hill.

The influence Yatagan Power Plant on the excess atmospheric ^{210}Pb fallout in the region is observed to be strongly dependent on the factors such as wind direction, existence of areas with high trees and ash stacks. Similar effects had been observed in another study realized by bioindicators at the same sites (Ugur et al., 2003; Ugur et al., 2004a). The present research will continue at inhabited regions in the basin.

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References

Flues M., Moraes V., Mazzilli B.P., 2002, The influence of a coal-fired power plant operation on radionuclide concentrations in soil, Journal of Environmental Radioactivity, 63, 285-294.

Fujiyoshi, R. Sawamura, S., 2004, Mesoscale veriability of vertical profiles of environmental radionuclides (^{40}K, ^{226}Ra, ^{210}Pb and ^{137}Cs) in temperate forest soils in Germany, Science of the Total Environment 320 177-188.

Huh, C.A., Su, C.C., 2004, Distribution of fallout radionuclides (^{7}Be, ^{137}Cs, ^{210}Pb and $^{239,240}Pu$) in soils of Taiwan, Journal of Environmental Radioactivity

Navas, A., Soto, J., Machin, J., 2002. 238U, 226Ra, 210Pb, 232Th and 40K activities in soil profiles of the Flysch sector (Central Spanish Pyrenees), Applied Radiation and Isotopes, 57, pp. 579-589.

Ugur, A., Ozden, B., Sac, M.M., Yener, G., 2003a, Biomonitoring of ^{210}Po and ^{210}Pb using lichens and mosses around a uraniferous coal-fired power plant in western Turkey, Atmospheric Environment, 37, 2237-2245.

Ugur, A., Yener, G., Sac, M. M., Altınbas, U., Kurucu, Y., Bolca, M., 2003b. Determination of soil Movements using radioactive lead and cesium profiles in agricultural lands in the Yatagan region formed by separate slope surfaces and percent declivities, The Scientific and Technical Research Council of Turkey (TUBITAK), Contract No: YDABCAG 100Y60 pp 104-106.

Ugur, A., Ozden, B., Sac, M.M., Yener, G., Altınbas, U., Kurucu, Y., Bolca, M., 2004a, Lichens and mosses for correlation between trace elements and ^{210}Po in the areas near coal-fired power plant at Yatagan, Turkey, Journal of Radioanalytical and Nuclear Chemistry, Vol. 259, No.1 87-92.

Ugur, A., Sac, M.M., Yener, G., Altınbas, U., Kurucu, Y., Bolca, M., Ozden, B., 2004b, Vertical distribution of the natural and artifical radionuclides in various soil profiles to investigate soil erosion, Journal of Radioanalytical and Nuclear Chemistry, Vol. 259, No.1 265-270.

Yener, G. and Uysal I., 1996, Low energy scintillation spectrometry for direct determinations of ^{238}U and ^{210}Pb in coal and ash samples, Applied Radiation Isotopes, 47, 93-96.

Walling D.E. and He Q., 1999, Using fallout lead-210 measurements to estimate soil erosion on cultivated land, Soil Science Society of America Journal, 63, 1404-1412.

Walling D.E., Collins A.L., Sichingabula H.M., 2003. Using unsupported lead-210 measurements to investigate soil erosion and sediment delivery in a small Zambian catchment, Geomorphology, 52, 193-213.

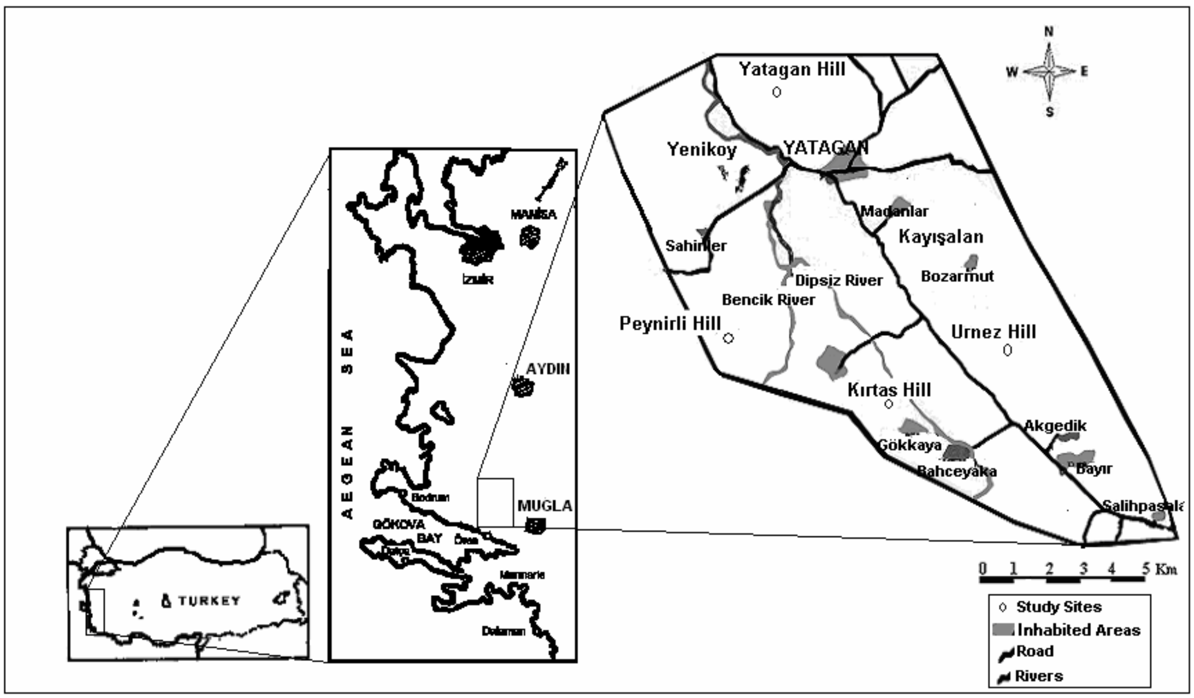

Fig. 1. Sampling locations in Yatagan Basin

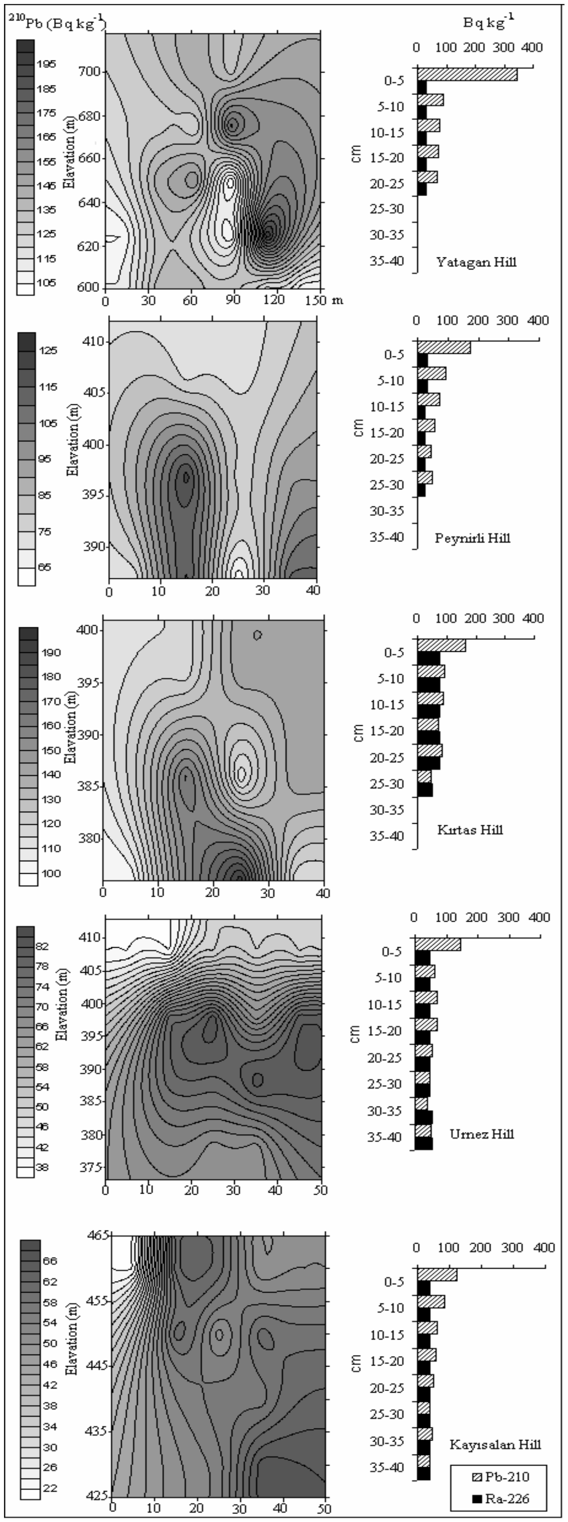

Fig 2. Spatial distribution of ^{210}Pb in bulk soil samples and Vertical distribution of ^{210}Pb and ^{226}Ra in soil profiles.

Table 1. Topographic data of sampling sites

Sampling Sites	Elevation (m)	Coordinate	Grid Cells (m^2)	Slope %	Total Area (m^2)
Yatagan Hill	700	37°21′N, 28°08′E	25x64	6-35	32000
Peynirli Hill	407	37°18′N, 28°06′E	10x40	5-27	3600
Kırtas Hill	396	37°17′N, 28°08′E	10x35	4-16	3150
Urnez Hill	408	37°18′N, 28°09′E	10x24	5-24	3360
Reference Hill	460	37°20′N, 28°10′E	10x28	5-13	3920
Total					46030