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RADIOACTIVE POLLUTION GENERATED BY THE ELECTRIC POWERS USING COAL AS COMBUSTIBLE

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Abstract: *A type of NORM (Normally Occurring Radioactive Materials) category is coal used as a fuel in power plants. The ash resulting from their burning is stored in the heaps near the thermal power stations and has a multiplication factor of the radionuclide concentration between 2 and 10, compared to the coal from which it originates. Even if in this case the radioactive pollution does not represent a significant danger for the population, this ash can be used in the construction of building materials, and thus through radon disintegration products emanating from these materials, can contribute to increasing the dose of ionizing radiation of the population, knowing that most of their lives and spend it inside buildings.*

Keywords: thermal power, coal, radioactive ash, radon

1. Introduction

The extraction and use of non-ferrous and radioactive metals, coal, geothermal waters, the operation of atomic power plants and nuclear explosions during the 1950s and 1960s altered the concept of radioactivity of the environment and led to the need for control and surveillance in all the components that define the notion of environment [1,2]. Thus, the radioactivity of the environment is given, together with the natural radionuclides existing since the formation of the Earth, and radioactive substances created exclusively in human activities (civil and military industries, medicine, scientific research, energetic reactors, waste etc.). Natural radioactivity is given by the cosmic radiation and the radioactive elements contained in the Earth's crust since the formation of our planet. Approximately 340 nuclides are found in the environment, of which 70 are radioactive [3,4]. Earth's natural radioactivity includes three major components:

a. Primordial radionuclides, having half-lives long enough to survive since they were created (those who are the heads of the three natural radioactive series);

b. Progenitors of these primordial radionuclides;

c. Cosmogenic radionuclides formed by the interaction of cosmic radiation with the atmosphere [5].

The activity of naturally occurring radionuclides and naturally occuring radioactive materials (NORM) can be artificially intensified by various technological processes, resulting in a new category of radionuclides called Technologically Enhanced Naturally Occurring Radiative Materials (TENORM)

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[6]. Lately, there has been an increase in the awareness of the danger of natural radioactive materials (NORM) as well as the increase in their concentrations in various non-nuclear industrial processes. There are cases where these naturally enriched radioactive materials (TENORM) may have the same levels of activity as waste with low levels of radioactivity from the nuclear fuel cycle. [7]

Artificial radioactivity is the result of experiments with nuclear weapons, the use of nuclear power plants and the use of man-made radionuclides in various applications (medicine, scientific research, industry, etc.) over 120 years after the discovery of radioactivity by Henry Bequerel.

In conclusion, the radioactivity of the environment (soil, air, water, food, plants, etc.) comes from natural radioactivity, but also from artificial radioactivity.

2. Chemical, radioactive and noise pollution generated by thermal power plants

As we know, technology, along with the extraordinary advantages offered to mankind, has brought many shortcomings, of which an important place is the pollution of the environment.

A thermoelectric or thermal power plant is an electric power plant that generates electricity based on the transformation of the thermal energy resulting from combustion of fuels. The electric current is produced by electric generators driven, in most cases, by steam turbines.

Materials resulting from coal combustion in thermo-power stations are:

- clay deposited on the bottom of the oven; is "heavy ash" and is the mineral part of coal; represents 20% of the combustion material;
- ash or "light ash" or "flying ash" that escapes from the chimney filters and reaches the atmosphere and then deposits on the ground; represents 80% of the combustion material;
- radon released into the atmosphere, increasing radioactivity even through its disintegration products, Bi-214 and Pb-210;
- hot gases.

In the burning process, harmful substances such as sulfur oxides (Sox), nitrogen oxides (NOx), carbon oxides (Cox) and ash dust are generated. Along with these, small amounts of hydrochloric and hydrofluoric acid are also produced.

Fly ash discharged through the chimneys of combustion plants of thermal power plants together with fine ash dust from ash storage dumps and coal dust from coal dumps or from transport or preparation is a solid noxious matter in the form of aerosols. [8]

In addition, the installations and equipment used for the coal supply of steam boilers, namely the sorting-crushing plant, the conveyor belts and the cup-drive machines, produce continuous noise pollution.

The dispersion of industrial, chemical and radioactive pollutants depends on the following factors:

- factors that characterize the emission source (exhaust sump height, its diameter, gas velocity and temperature, the amount of pollutant emitted per unit time, the physical and chemical properties of the pollutant);
- factors that characterize the area where the emission took place (topography and roughness of the land);
- meteorological factors (air currents characterized by direction and velocity, thermal stratification of the atmosphere).

Dispersing in the environment, pollutants of different types get into the air, water, soil [9-19] and produce numerous negative effects on plants [20-27], animals, and humans [28].

3. Radiation pollution generated by thermal power plants

Average annual ash and slag yields from a coal-fired power plant vary mainly with the installed power of the power plant, the quality and degree of coal fragmentation, and the characteristics of the combustion boiler.

In our country, at all power stations that use coal as the main fuel, the transport of ash to the dumps is made by hydraulic systems because of the large quantities to be transported.
In Romania the ash dumps do not have high heights, but occupy a large area of land.
Ash and slag represent the unaltered solid residues resulting from the combustion of coal in power plants and consist of calcite, pyrite, clay and other minerals that are divided and decomposed in the combustion process.
The main fraction resulting from combustion is ash (70 ÷ 90%) compared to slag and other resulting materials. Its color may be gray or light gray, depending on the unbound carbon content.
All coal varieties contain natural radioactive isotopes in certain concentrations. By burning them in the center, there is a concentration of radioactive isotopes in the combustion products which are subsequently discharged into the environment. [29]
The table below shows the specific radioactive activities of the main radionuclides contained in the coal extracted from the mines in Romania:

Table 1 The specific radioactive activities of the main radionuclides contained in the coal extracted from the mines in Romania

Natural radioisotope	Λ_s (Bq/kg)
^{40}K	30 ÷ 650
^{238}U	1 ÷ 100
^{232}U	1 ÷ 50
^{226}Ra	1 ÷ 150

Charcoal contains ^{40}K, uranium, thorium and all radionuclides in the disintegration chains. Also, radon from the natural radionuclide disintegration chain is exalted by dislocation and granulation inside the combustion chamber, increasing the concentration of radon within it.
The specific activity of the main radionuclides in the fly ash emitted from coal-fired power plants in Romania is presented in the table below:

Table 2 The specific activity of the main radionuclides in the fly ash emitted from coal-fired power plants in Romania

Natural radioisotope	Λ_s (Bq/kg)
^{40}K	160 ÷ 1200
^{238}U	2 ÷ 312
^{226}Ra	3 ÷ 520
^{210}Pb	10 ÷ 500
^{210}Po	2 ÷ 170
^{232}Th	2 ÷ 170

It can be seen that the radioactivity resulting from the combustion of coal is 2 ÷ 10 times higher than that of the primary fuel.
Worldwide, according to the literature, the average specific activity of 238U and 232Th of coal is about 20 Bq / kg, with values ranging from 5 to 300 Bq / kg.
During coal combustion, organic compounds are gasified (water vapor and carbon dioxide), and inorganic ones containing naturally occurring radionuclides are concentrated in ash. Generally, the radionuclide amplification factor in ash, as shown in the tab. no. 2 is approximately equal to 10. Taking into account the low

migration rate of ash radioisotopes, the use of this material in road construction is not subject to major restrictions.

However, the use of ash as building material for buildings and dwellings may result in direct and indirect exposure of the population through radon emanations, the main routes of exposure being the ingestion and inhalation of radioisotopes Pb-210 and Po-210. [30]

The table below lists the values of the specific activities for ash samples from thermal power stations worldwide, values specified in the references in the first column of the table

Table 3 The specific activity of ashes from thermal power plants reported by foreign authors

Reference	Sample	Radionuclide (Bq/kg)							
		Ra^{226}	Th^{232}	Pb^{210}	U^{238}	U^{235}	K^{40}	Po^{210}	Ac^{228}
G.G. Pandit, S.K. Sahu and V.D. Puranik, Natural radionuclides from coal fired thermal power plants – estimation of atmospheric release and inhalation risk, Radioprotection, vol. 46, no. 6 (2011) S173–S179 EDP Sciences, 2011	1	77,7	125,8	40,5	60,3	-	-	-	-
Craig Heidrich, Sue Brown, Doug Collier, Naturally occurring radionuclides in Australian coal combustion products, World of coal ash Conference – Mai 9-12 Denver, CO, USA.	1	110	120	-	-	-	450	-	-
	2	90	130	-	-	-	190	-	-
	3	110	150	-	-	-	570	-	-
	4	30	70	-	-	-	100	-	-
	5	60	90	-	-	-	320	-	-
	6	140	200	-	-	-	210	-	-
	7	7	-	-	-	-	20	-	-
	8	40	7	-	-	-	-	-	-
	9	160	280	-	-	-	70	-	-
	10	150	290	-	-	-	60	-	-
L. Mljač and M.Križman, Environmental radioactivity due to fly-ash disposal results of a monitoring programme, Symposium on radiation protection in neighbouring countries in Central Europe – 1995	1	9,5	-	-	9,5	-	-	-	-
Ts. Erkhembayar, T.Ulaanbaatar, M. Baatarkhuu, N.Chimedtsogzol, Ts.Otgontuya, Soil, Coal and Ash Radioactivity around Baganuur Coal Deposit in Mongolia, Strategic Technology (IFOST), 2013 8th International Forum on 03 October 2013	1	163	39	-	-	-	196	-	-
	2	123	67,7	-	-	-	237	-	-
Analysis of natural radionuclides in coal, slag and ash in coal-fired power plants in Serbia - M.M. Janković, D.J. Todorović, J.D. Nikolić,University of Belgrade, Institute Vinča, Radiation and Environmental Protection Department, 11001 Belgrade, Serbia, 2011	1	120	72	-	129	7,3	360	-	-
J Suhana, M. Rashid, Air Resources Research Laboratory, Malaysia – Naturally occurring radionuclides in particulate emission from a coal fired power plant: A potential contamination ?, Journal of Environmental Chemical Engineering, 2016	1	-	13,2	-	9,8	-	-	-	-
	1	-	-	-	-	-	-	65,6 ± 6,7	-
	2	-	-	-	-	-	-	136	-

^{210}Po distribution after high temperature processes in coal fired power plants - Wang Chuangao, Liu Ruirui, Li Jinfeng, Huang Zhijun, Pan Jingshun, Luo Zhiping, Chen Ling, Wang Zhongwen, Pan Ziqiang, Department of Radiation Safety, China, 2017								± 32	
	3	-	-	-	-	-	-	181 ± 8,3	-
	4	-	-	-	-	-	-	117 ± 2,1	-
	5	-	-	-	-	-	-	94,1 ± 12	-
	6	-	-	-	-	-	-	64,5 ± 9	-
Rare earth elements in fly ash created during the coal burning process in certain coal fired power plants operating in Poland – Upper Silesian Industrial Region, Danuta Smolka Danielowska, Faculty of Earth Sciences, University of Silesia, Poland, 2010	1	-	84±3	-	32±5	14,6±1	732±20	-	102±2
	2	177±20	52±2	-	78±3	5,6±0,5	740±20	-	102±2
	3	99±32	99±4	-	79±2	12,3±1,5	772±19	-	73±2
	4	137±38	82±3	-	69±3	16,5±1	682±19	-	72±2
	5	78±2	135±3	-	33±3	12±1,1	624±23	-	84±3
	6	56±16	134±3	-	38±3	6±1,9	578±20	-	72±2
	7	20±8,2	77±3	-	58±5	18±1,5	389±15	-	99±4
	8	-	34±2	-	12±1	18±0,5	377±16	-	100±2
	9	-	78±3	-	16±2	8,3±2,3	760±19	-	99±2
	10	-	64±3	-	18±2	18±1	720±17	-	111±4
	11	175±23	104±2	-	76±3	12,4±1,5	735±19	-	26±2
	12	66±23	118±3	-	49±4	10±1,8	679±21	-	25±2
	13	72±14	105±3	-	33±4	11±1,3	733±19	-	72±2
	14	176±12	97±3	-	77±5	14,8±1,4	795±24	-	53±2
	15	130±22	141±4	-	76±2	16±6	724±16	-	89±2
	16	48±8	115±3	-	68±3	16±1	788±17	-	99±3
	17	178±31	99±3	-	44±4	12,6±1,8	698±14	-	101±2
	18	177±18	111±3	-	32±5	10,7±1,8	786±17	-	102±2
	19	-	103±3	-	36±3	11,5±1,2	771±21	-	88±2
	20	-	121±3	-	58±3	17,2±1,6	790±19	-	86±3
	21	168±21	112±3	-	56±5	18±1	766±18	-	100±2
	22	99±15	107±3	-	57±4	15,9±1	744±18	-	98±2
	23	85±17	127±3	-	66±2	14,7±1,3	734±15	-	86±2
	24	148±22	119±3	-	39±5	13,8±1,2	770±20	-	81±3

Modeling Radionuclides Dispersion and Deposition Downwind of a Coal-Fired Power Plant - Dinis M.L., Fiúza A., Góis J., Carvalho J.M.S., Castro A.C.M., Centre for Natural Resources and the Environment (CERENA), Instituto Superior Técnico - IST, Av. Rovisco Pais, Lisabona, Portugalia	1	53,97	40,13	-	-	-	901,44	-	-

4. Conclusions

Concentrations of natural radionuclides in ash dumps do not lead to a significant increase in the absorbed dose rate, as evidenced by measurements with ionizing radiation flow meters on the heap surfaces at millimeter distances.

Particular attention must, however, be given to the manufacture of building materials (cement, bricks, etc.) from the ashes of these dumps, which can amplify the concentration of radon in enclosed spaces where man is forced to spend much longer especially since the ICRP (International Commission on Radiological Protection), through its studies in recent years, alerts itself to the risks to which it is exposed to the concentrations of this radioactive gas.

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