AP19678770 "Radioecological aspects of power coals and ash and slag waste radioactivity in the context of their impact on the environment" – p.m. Pak Yu.N.

Relevance

The relevance of the results is associated with the study of radioecological aspects of natural radioactivity of power coals and ash and slag waste in the context of their negative impact on the environment.

The radiation hazard associated with natural radioactive elements contained in coal is one of the important problems of coal power engineering, which is underestimated in Kazakhstan. Systematic monitoring of radioecological safety is necessary to reduce the radiation exposure of personnel and the population living in areas where coal-fired thermal power plants are located. Existing radiation safety standards are limited to the content of radionuclides only in ash and slag waste when used for construction purposes.

Objective of the project

The objective of the project is to assess the impact of the use of coals containing natural radioactive elements in fuel energy on the radioecological situation of the environment.

Expected and achieved results

Achieved results

In the coming decades, the share of coal in electricity production will be even more significant. This exacerbates environmental problems due to radiation pollution of the environment with radionuclides concentrated in ash and slag waste and fly ash.

The natural radioactivity of coals in Kazakhstan has been poorly studied. Increased concentrations of radionuclides have been found in a number of deposits (Karazhyra, Maikubinskoye). The average uranium and thorium content in coals in Kazakhstan is 1.8 and 2.2 g / t, and in ash - 8.7 and 10.6 g / t. Ash and slag dumps are becoming a man-made deposit of radionuclides. When coal is burned at thermal power plants, some of the radionuclides are carried out into the atmosphere by flue gases. The innovative nature of this project lies in the study of the distribution and forms of occurrence of ERE in coals to model the behavior of radionuclides during combustion and predict their potential emission into the environment.

In 2023, the features of the distribution of natural radionuclides of uranium, thorium and potassium in power-generating coals, their specific activity and forms of their presence depending on the coal grade and its quality (ash content) were studied. Using power-generating coals as an example, specific radioactivities (concentrations of uranium (radium), thorium and potassium-40) were determined. In ash and slag waste obtained during combustion of power-generating coals, specific radioactivities of natural radioactive elements were determined. In the process of processing the analysis results, preliminary conclusions were made about a significant concentration of the content of natural heavy radionuclides in ash and slag waste. A sufficient number of selected representative samples and specimens, data on the specific activity of each radionuclide, obtained on the basis of their analysis by modern nuclear radiometric, radiochemical and X-ray methods, were determined. Primary representative samples and specimens of power-generating coals of Kazakhstan were selected (using the Ekibastuz and Karaganda deposits as an example). The selected samples were prepared for analysis for uranium, thorium and potassium-40 according to GOST. 30 coal samples and 30 ash and slag waste samples were submitted for determination of specific radioactivity of natural radioactive elements in them using a certified gamma-spectrometric method. Partial studies were performed to verify the correctness of the analysis and to assess random errors. Analytical studies were conducted to develop a model for the behavior of natural radionuclides during coal combustion at thermal power plants and to predict the potential emission of these radionuclides into the environment.

1 article was published in a domestic publication recommended by KOKSNVO.

The distribution patterns of natural radioactive elements in fossils were studied in **2024**. It was found that there is a lot of data on the forms of uranium, thorium and potassium-40 in fossil coals. Coals with a below-clarke uranium content are characterized mainly by the mineral form of occurrence, and coals enriched in uranium are characterized by the organic form. Estimation of the uranium balance by the forms of occurrence in different types of coal at different concentrations remains problematic. There is no clarity on the role of diagenesis and coal metamorphism on the form of uranium. The accumulation of uranium in coal depends on the formation of coal seams. As a result of sorption, uranium accumulates in organic matter or in clastogenic material. Sometimes a significant amount of uranium is associated with soluble aluminosilicate compounds. In coals with an abnormal uranium content, the dispersed form predominates. In the early stages of coal formation, the bulk accumulates in organic matter. In the process of coalification (change in the structure of organic matter) the ratio of uranium species changes. The role of mineral species increases. The geochemistry of thorium has been studied. An idea of the mineral species of thorium in coals has been formed. The main carriers are monazite, rare earth phosphates, silicates and aluminosilicates. There is also information on the possibility of Th concentration in organic matter. In general, thorium in coals is characterized by a high significant positive relationship with the ash content of coal. Medium-ash coals are characterized by Th in organic matter. In the process of coal metamorphism, species change with the formation of their own minerals. Radionuclide K40 is mainly contained in clay minerals, its concentration is closely related to the ash content of coal. A generalization of world experience in the natural radioactivity of coals indicates poor study of coal deposits in Kazakhstan for the presence of natural radioactive elements (uranium, thorium, potassium-40). Coals of Kazakhstan are generally characterized as slightly radioactive. Clarke contents of uranium and thorium in hard coals are 1.9 g/t and 3.1 g/t, respectively. The content of these natural radionuclides in the main coal deposits (Ekibastuz, Karaganda) is close to the clarke. However, in the ridge of deposits (Shubarkol, Maikuben, individual layers of oxidized coals), elevated concentrations of uranium are observed. During the combustion of coals even with low concentrations of radionuclides in the combustion waste (solid ash, slag, fly ash), the content of radionuclides (uranium-238 and its decay products, thorium-232 and its decay products, and potassium-40) increases by 3-8 times in relation to the original coal. Using the example of Ekibastuz and Karaganda coals with different ash contents, the specific activities of the main radionuclides (U238 (Ra), Th232 and K40) were determined by instrumental analysis of 25 coal samples from the Ekibastuz deposit using the gamma-spectrometric method based on a semiconductor detector. The concentrations (specific activities of radionuclides) were determined: uranium-238 (radium-226) - 11.2-14.9 Bq / kg; thorium-232 - 11.7-13 Bq / kg; potassium-40 - 28-63 Bq / kg. In the ash and slag waste of the state district power plant burning Ekibastuz coal, the specific activities were U (Ra) - 53-70 Bq / kg; Th - 50-67 Bq / kg; K - 220-270 Bq / kg. The concentration factors of radionuclides (the ratio of the concentration of a radionuclide in the ash and the original coal) vary within the range of 4.2-8.6. In the ash and slag waste of the Toparskaya GRES, which burns Karaganda coals, the concentration factors of radionuclides vary within the range of 2.5-10.9. The results obtained indicate that when burning low-radioactive coals, radionuclides are concentrated in the ash and slag waste. The degree of concentration depends on many factors: the quality and brand of the coal burned, the concentration of radionuclides and their form of occurrence, combustion technologies and conditions, etc. Ash dumps, where ash and slag are stored, occupy vast territories and, in fact, turn into quasi-technogenic deposits of natural radioactive nuclides and many toxic, rare and rare earth elements. 1 article was published in a domestic edition recommended by KOKSNVO, 2 Eurasian patents were received. The research results were presented at 3 international conferences (KazNiTU, Almaty, RSUH named after S. Ordzhonikidze, Moscow, branch of Moscow State University named after Lomonosov, Dushanbe), 1 textbook, 1 teaching aid.

For 2025

Experimental data on the specific activity of each radionuclide in fly ash residues were determined using modern instrumental analysis methods. 2 abstracts of reports for International Conferences were prepared. The contribution of the specific activity of each natural radionuclide in fly ash was determined using radiochemical methods.

1 article was published in a domestic publication recommended by KOKSNVO, 1 patent of the Republic of Kazakhstan was received, 2 articles were published in peer-reviewed scientific journals indexed in the Science Citation Index Expanded of the Web of Science database and (or) having a CiteScore percentile in the Scopus database of at least 50 (fifty).

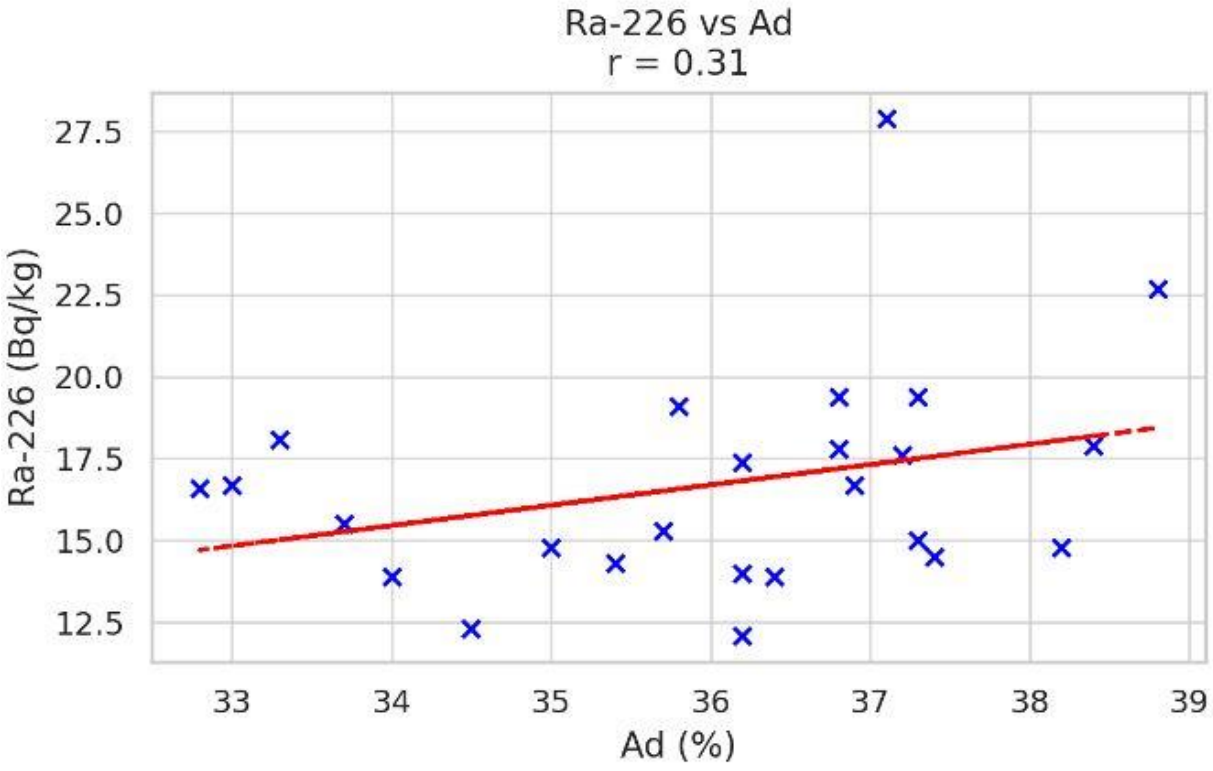

Figure 1 – Dependence of the concentration of Ra-226 in coal on the ash content of Ad

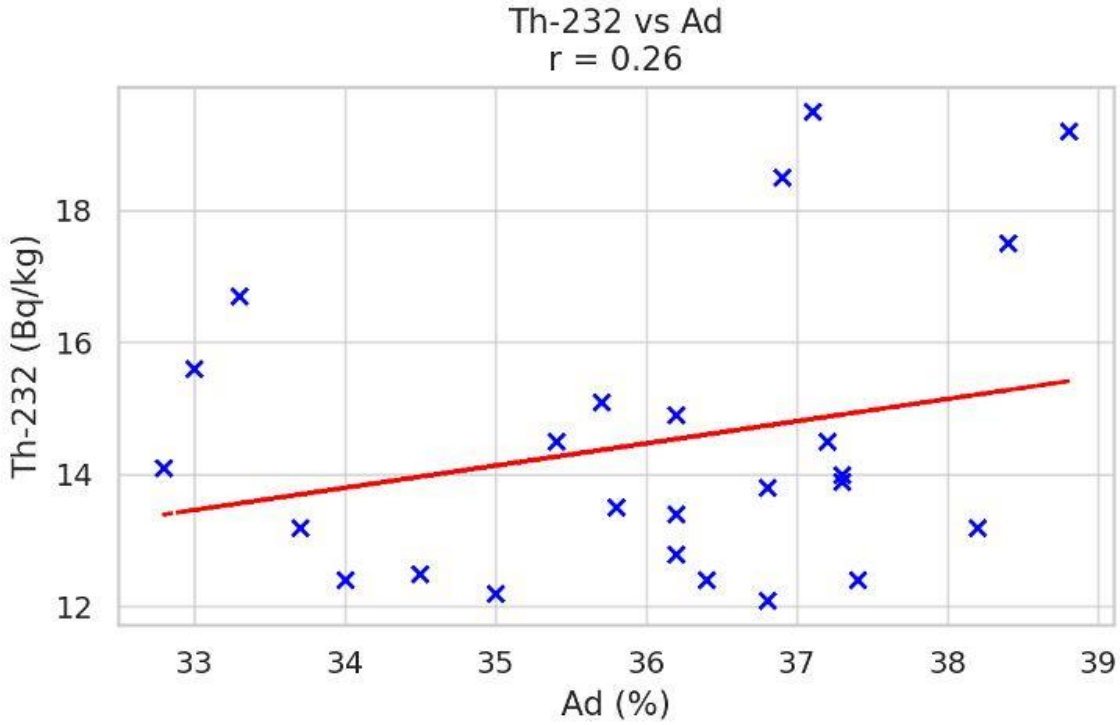

Figure 2 – Dependence of the concentration of Th-232 in coal on the ash content of Ad

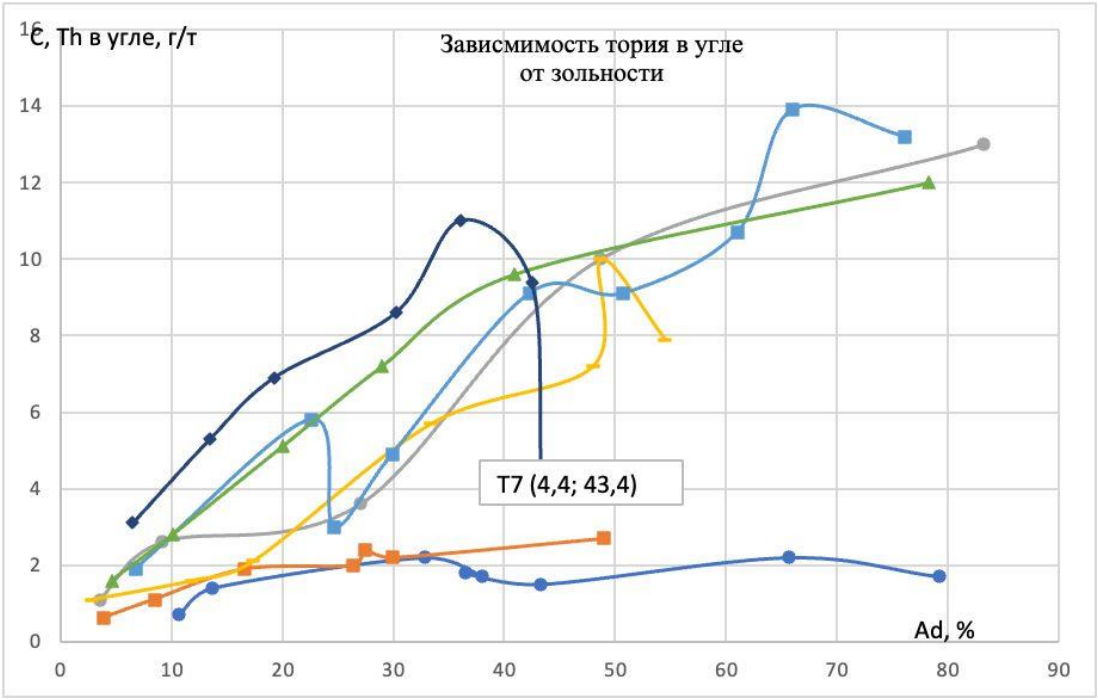

Figure 3 – Dependence of thorium in coal on ash content

List of publications

2023:

1. Pak D., Tebayeva A., Pak Yu. Instrumental express analysis of ferromanganese ores by nuclear-geophysical method. Труды университета / КарТУ им. А. Сагинова. – Караганда, – Вып. 4, 2023, – С. 104-108.

2024:

1. Пак Д.Ю., Тебаева А.Ю., Пак Ю.Н. Геолого-геофизическое опробование железных руд гамма-альбедным методом. Труды университета / КарТУ им. А. Сагинова. – Караганда, – Вып. 2, 2024, – С. 100-107.

2. Пак Ю., Пак Д.Ю., Тутанов С.К., Булатбаев Ф.Н., Бегимбетова А.С., Кенетаева А.А., Тебаева А.Ю., Есендосова А.Н. Гамма-альбедный способ контроля эффективного атомного номера сложного вещества. Евразийский патент №046032, 2024.

3. Пак Ю., Пак Д.Ю., Тутанов С.К., Пономарева М.В., Пономарева Е.В., Тебаева А.Ю., Матонин Вл. В. Радиометрический способ оценки содержания природных радиоактивных элементов в углях. Евразийский патент №046319, 2024.

4. Пак Д.Ю., Тебаева А.Ю., Пак Ю.Н. Лабораторный практикум по ядерным технологиям в геолого-геофизических исследованиях (III часть). Издательство НАО КарТУ им. А. Сагинова, 74с, 2024, Учебное пособие.

5. Pak Yu.N., Ibatov M. K., Pak Yu.N., Tebayeva A. Yu. Fundamentals of Scientific Research and Inventive Creativity. Учебник с грифом МНиВО РК. Караганда, Изд-во КарТУ, 2024, 151 с.

6. Пак Д.Ю., Тебаева А.Ю., Пак Ю.Н. Ядерно-физический метод контроля зольности угля. Международная научная конференция «Геология в пространстве и времени», филиал МГУ имени М.В. Ломоносова, г. Душанбе, 2024, с.100-1012.

7. Тебаева А.Ю., Пак Д.Ю., Пак Ю.Н. Анализ железомарганцевых руд с помощью ядерно-геофизического способа. Материалы XI Международной научной конференции молодых ученых «Молодые – Наукам о Земле», Москва, РГГУ им. Орджоникидзе, 2024.

8. Пак Д.Ю., Тебаева А.Ю., Пак Ю.Н. Методологические исследования ядерно-геофизического контроля калорийности крупнодисперсного топлива. Труды Международной научно-практической конференции «SATBAYEV INTERNATIONAL CONFERENCE 2024 (Сатпаевские Чтения – 2024). Интеграция науки и технологий: Путь к устойчивому развитию, с.100-1012.

2025:

1. Y. Pak, D. Pak, D. Ibragimova, V. Matonin, A. Tebayeva. Assessment of Natural Radioactivity and Trace Element Composition of Coals and Ash and Slag Waste in Kazakhstan. Atmosphere 2025, 16, 125.

2. Пак Ю., Пак Д.Ю., Тебаева А.Ю., Пономарева Е.В., Билимова Е.С., Турысбекова А.С., Жумагулов С.Е., Ахмет Е. К. Ядерно-радиометрический способ датирования геологических образований. Патент РК № 37186

3. Pak D., Safarov R., Pak Yu., Tebayeva A., Kolmakov Yu. Using the spectrometric gamma method to solve petroleum geophysics problems. Труды университета / КарТУ им. А. Сагинова. – Караганда, – Вып. 2, 2025, – С. 131-137.

4. Y. Pak, D. Pak, V. Matonin, D. Ibragimova, P. Timoshenko, Y. Barkov, A. Tebayeva, P. Medvedev. Study of radon radiation in the area of the Akchatau polymetallic mine, Republic of Kazakhstan. Atmosphere 2025, 16, 769.

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Information for potential users

Research on the natural radioactivity of coals and ash and slag wastes arising from their combustion in coal power engineering is necessary for fuel energy enterprises and state environmental control services.

Application area
Earth and environmental sciences

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