

## **AP23485184 "Technology of nuclear-geophysical testing of coals using gamma-ray spectrometry of natural radioactive elements" – Pak Yu.N.**

### **Relevance**

Currently, mining enterprises mainly use standard coal sampling methods, which involve the collection of primary samples, their cutting (crushing, grinding, reduction) and direct thermal-gravity analysis, which consists of burning an analytical sample (~0.1 mm) of coal (1-2 grams) with subsequent calculation of ash content. Significant disadvantages of the traditional sampling method are high labor intensity and low representativeness (the quality of a coal batch (hundreds of tons) is assessed based on the results of thermal-gravity analysis of an analytical sample). In some cases, the final stage of sampling is replaced by instrumental nuclear-physical methods, which involve the use of radioisotope sources of gamma and neutron radiation. At the same time, errors due to the heterogeneity of coals, which arise at the labor-intensive stages of sampling and their sample preparation, remain. An innovative approach to testing solid fuel is proposed, consisting in measuring the spectrometry of gamma radiation emitted by natural radioactive elements (uranium-238; thorium-232 and potassium-40), which will allow assessing the quality of coals in large masses without preliminary sample preparation with high sensitivity and accuracy. The practical significance of the research results consists in the creation of a new nuclear-geophysical technology for testing coals by spectrometry of natural gamma radiation, which allows, based on operational and objective information on ash content, to introduce a quality management system in the process of coal mining and processing.

### **Project objective**

The objective of the project is to develop a new technology for nuclear-geophysical testing of coals using spectrometry of natural gamma radiation of natural radioactive elements (U238, Th232, K40) with selective consideration of the specific activity of each radionuclide based on the interpretation and algorithmic justification of complex gamma-spectrometric measurements, ensuring high sensitivity of coal quality assessment in large masses.

### **Expected and achieved results (2024)**

The features of the existing standard method for sampling a coal batch were studied. It involves representative selection of primary samples (their quantity and weight), their crushing, reduction, grinding and preparation of analytical samples (~0.074 mm) for thermal gravimetric analysis of ash content. Coal is considered heterogeneous at each stage of its processing. Heterogeneity is estimated by the standard deviation of the quality parameter (coal ash content). At each stage of standard sampling, a component error is formed: due to selection of primary samples, crushing, reduction, grinding, preparation of analytical samples and directly thermal gravimetric analysis. It was revealed that the error due to sampling is the most significant. It is about 70-80% of the total sampling error. All stages of standard coal sampling are very lengthy and introduce a noticeable error in assessing the quality of the fuel and cannot be considered as a means of managing the quality of coal at the stages of mining and processing. Based on the obtained results, materials were prepared for improving the existing sampling system based on natural gamma radiation spectrometry.

Representative primary samples of coal from the Ekibastuz and Karaganda deposits were selected. The selected primary samples of different component and granulometric composition were subjected to standard sample preparation schemes: drying, crushing, reduction, grinding and bringing to an analytical size (~ 0.074 mm). 200 samples of coal from these deposits were prepared for instrumental determination of concentrations (specific activity) of uranium-238 and their decay products, thorium-232 and their decay products and potassium-40 using various nuclear-physical

methods (gamma spectrometry, neutron activation, X-ray fluorescence). Work has begun on instrumental analysis of the prepared samples to assess the specific activity of various radionuclides. The results of studies on the distribution of natural radioactive nuclides (U, Th and their decay products) in fossil coals and their forms of occurrence are summarized. In coals with a relatively low uranium content, the mineral form of their occurrence predominates. Coals richer in uranium contain it mainly in organic matter. The bulk of Th is in the mineral part of coal. The distribution of U, Th in coal basins is generally uneven and is determined by the combined influence of a number of factors: the degree of coalification and age, heterogeneity of rock composition, ash content, etc. Preliminary results on the relationships between the main components of coal with ash content and specific activity of radionuclides are obtained.

### **Expected and achieved results (2025)**

The justified analytical gamma lines of uranium-238, thorium-232 and potassium-40 were selected in terms of the maximum relative intensity of gamma lines. Depending on the type of spectrometer (detector), the optimal energy windows (intervals) were selected in the area of the selected analytical gamma lines of the determined radionuclides, ensuring maximum sensitivity. Instrumental signals of gamma spectrometric measurements were found that are closely related to the concentrations of the determined radionuclides in the sampled coals.

### **List of publications**

#### **2024:**

1. Пак Ю., Нургужин М.Р., Пак Д.Ю., Тебаева А.Ю., Николаенко Н.А. Инструментальный способ радиометрического определения удельной радиоактивности золошлаковых отходов. Евразийский патент №047897.

2. Пак Ю., Пак Д.Ю., Тебаева А.Ю., Айткалиев А.К., Оспанова С.М. Инструментальный способ рентгенорадиометрического анализа руд сложного состава. Евразийский патент №047642.

3. Тебаева А.Ю., Ибрагимова Д.А., Пак Д.Ю., Пак Ю.Н. Природная радиоактивность ископаемых углей: Проблемы и перспективы использования. Материалы VI Международной конференции молодых ученых и специалистов памяти академика А.П. Карпинского, Санкт-Петербург, Институт Карпинского, 2024, с.183-186.

#### **2025:**

1. Пак Ю., Пак Д.Ю., Нургужин М.Р., Тебаева А.Ю., Ибрагимова Д.А., Оспанова Ж.Н. Гамма-альбедный способ инструментального опробования твердого топлива. Патент РК №37162.

2. Пак Ю., Сагинтаева С.С., Пак Д.Ю., Тебаева А.Ю., Сулейменов Н.М., Кабыкен А.Б. Инструментальный способ ядерно-геофизического контроля качества твердого топлива. Евразийский патент №049325.

3. Pak D., Pak Y., Ibragimova D., Tebayeva A., Nikolayenko N. Assessment of Radioecological Safety of Coals and Ash and Slag Waste. Труды университета / КарТУ им. А. Сагинова. – Караганда, – Вып. 1, 2025, – С. 121-127.

4. Pak Yu., Pak D., Tebayeva A., Aitkaliyev A. Instrumental testing of quasi-binary ore materials by the gamma-albedo method. Журнал «Material and Mechanical engineering technology», №2, 2025, Караганда, С. 3-10.

### ***Research team and project management***

1. Pak Yuri Nikolaevich - scientific supervisor, Doctor of Technical Sciences, prof.

h-index Scopus: 6  
<https://orcid.org/0000-0002-0699-6764>  
Scopus Author ID: 7102674136  
ResearcherID: V-8724-2018

2. Pak Dmitry Yurievich – responsible executive, Ph.D., associate professor.

h-index Scopus: 5  
<https://orcid.org/0000-0002-7215-7846>  
Scopus Author ID: 45561507200  
ResearcherID: V-8176-2018

3. Kropachev Petr Aleksandrovich – performer, candidate of technical sciences, associate professor.

h-index Scopus: 3  
Scopus Author ID: 55378112200

4. Lee Elena Sergeevna – performer, senior lecturer, PhD master

h-index Scopus: 2  
<https://orcid.org/0000-0003-4856-5222>  
Scopus Author ID: 57200985313  
ResearcherID: X-8542-2018

5. Tebaeva Anar Yulaevna – performer, master

h-index Scopus: 1  
Scopus Author ID: 57367955300  
<https://orcid.org/0000-0001-5404-7195>

6. Ibragimova Diana Andreevna – performer, PhD

h-index Scopus: 1  
Scopus Author ID: 57901957700  
<https://orcid.org/0000-0002-2588-3028>

7. Vdovkina Darya Igorevna – performer, master, geologist of the mining sector

h-index Scopus: 1  
Scopus Author ID: 57476789200

### ***Information for potential users***

The radioecological situation in the areas of operating thermal power plants based on monitoring the level of radioactivity will allow an objective assessment of the impact of the fuel and energy sector on the natural environment and predictive recommendations on the rational use of ash and slag waste in the construction industry.

### ***Application area***

Earth and environmental sciences

*Date of information update: 0.07.2025*