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# DETERMINATION OF ASH CONTENT IN COAL BY X-RAY FLUORESCENCE ANALYSIS

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*Abstract*

This article discusses the advantages of X-ray fluorescence analysis (XRF) techniques for the determination of ash in coal. The quality of coal depends on the amount of ash contained in it. On the other hand, ash causes irreversible environmental damage when using coal as a source of energy. Since coal is considered as the most important source of energy, coal quality is directly related to ash, which correlates with its non-combustible minerals and elements. Some elements such as S (sulfur), Ti (titanium), Ca (calcium), Fe (iron) after burning coal can have an adverse impact on the environment. Thus, we have demonstrated in this study how we can determine the ash content consisting of non-combustible minerals in the composition of coal and, thus, assess the quality of coal using X-ray fluorescence research. It also describes how we can determine coal ash samples using the XRF analyzer 123-1 in online, which is one of the most optimal methods in nuclear physics.

**Keywords**: X-ray fluorescence, analysis, energy, ecology, ash, coal.

*Аннотация*

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**ОПРЕДЕЛЕНИЕ СОДЕРЖАНИЯ ЗОЛ В УГЛЕ С ПОМОЩЬЮ РЕНТГЕНОФЛУОРЕСЦЕНТНОГО АНАЛИЗА**

В этой статье обсуждаются преимущества методов рентгенофлуоресцентного анализа (РФА) для определения золы в угле. Качество угля зависит от количества содержащейся в нем золы. С другой стороны, зола наносит необратимый ущерб окружающей среде при использовании угля в качестве источника энергии. Поскольку уголь считается наиболее важным источником энергии, качество угля напрямую связано с золой, которая соотносится с ее негорючими минералами и элементами. Некоторые элементы, такие как S (сера), Ti (титан), Ca (кальций), Fe (железо), после сжигания угля могут оказывать неблагоприятное воздействие на окружающую среду. Таким образом, в этом исследовании мы продемонстрировали, как мы можем определить зольность, состоящую из негорючих минералов в составе угля, и, таким образом, оценить качество угля с помощью рентгеновских флуоресцентных исследований. В нем также описывается, как мы можем определять пробы угольной золы в режиме онлайн с помощью РФА анализатора 123-1, который является одним из самых оптимальных методов в ядерной физике.

**Ключевые слова:** рентгенофлуоресценция, анализ, энергия, экология, зола, уголь.

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**КӨМІРДІҢ КҮЛІН РЕНТГЕН ФЛУОРЕСЦЕНЦИЯ ЗЕРТТЕУ ӘДІСІМЕН АНЫҚТАУ РЕНТГЕН ФЛУОРЕСЦЕНЦИЯ ЗЕРТТЕУ ӘДІСІМЕН КӨМІРДІҢ ҚҰРАМЫНДАҒЫ КҮЛДІ АНЫҚТАУ**

Бұл мақалада көмірдегі күлді анықтаудың рентген флуоресценттік зерттеу (РФЗ) әдістерінің артықшылықтары туралы айтылады. Көмірді энергия көзі ретінде пайдаланған кезде, қоршаған ортаға зиян келтіреді. Көмір энергияның маңызды көзі болып саналатындықтан, көмірдің сапасы оның құрамындағы күлге тікелей байланысты яғни оның жанбайтын бөлігіндегі минералдар мен элементтерге байланысты. Көмір жанғаннан кейін S (күкірт), Ti (титан), Ca (кальций), Fe (темір) сияқты кейбір элементтер қоршаған ортаға кері әсерін тигізуі мүмкін. Осы зерттеуде біз көмір құрамындағы жанбайтын минералдардан тұратын күлді РФЗ әдісімен қалай анықтауға болатындығын және сол арқылы көмірдің сапасын қалай алдын-ала болжап бағалауға болатындығын көрсеттік. Сонымен қатар, көлемі кішігірім, салмағы аз РФЗ-123 анализаторының көмегімен көмір күлін онлайн режимде қалай анықтауға болатындығын көрсеттік.

**Түйін сөздер:** рентген флуоресценция, зерттеу, энергия, экология, күл, көмір.

**Introduction**

Using X-rays, can be obtained important information about the atomic structure of a solid, the electronic structure of chemical bonds, and its elemental composition. From this point of view, the study of matter by X-rays is the most convenient and versatile technical tool in modern science and technology [1].

In recent years, the study of the elemental composition of coal by the method of X-ray fluorescence anysis has begun in many countries around the world. As a result of this research, it was proved in practice that by determining the elemental composition of coal and its ash, its quality can be immediately assessed in advance in the ground, during its production, preparation, transportation and combustion. It is also possible to quickly determine the ash, moisture, calorific value and carbon content of sulfur, arsenic, iron and other microelements in the coal with the help of modern X-ray analyzers with high sensitivity and separation of elements from coal [2-3]. Coal ash is a non-combustible mineral substance found in the combustion of coal. The higher the mineral content of coal, the higher the ash content of coal. Coal ash is based on a mixture of elements such as silicate, aluminum, iron, calcium, magnesium, titanium and potassium [4]. The study of the composition of coal ash by the methods of nuclear physics has been carried out at a high pace over the past 20 years, and many research scientists in this field have published new research techniques and methods [5-6]. Recent advances in the use of X-ray fluorescence have shown that many elements in coal and its ash can be studied simultaneously, thus allowing to determine the most economically important parameters that lead to the classification of coal [7]. As in many countries around the world, coal is the main source of energy in Kazakhstan. According to some data, Kazakhstan's coal reserves are about 35 billion tons. Kazakhstan ranks 8th in the world in terms of coal reserves and has 4% of the world's total coal reserves. The most valuable energy and coking coal for the industry are concentrated in 16 fields [8-9]. The Republic of Kazakhstan is one of the ten largest coal producers in the world market, and the third largest in the CIS in terms of reserves and the first in terms of per capita coal production and it is planned to increase coal production in the coming years [10-11].

**Method for determination of ash in coal by XRF**

Detection of ash in coal by XRF method is carried out by studying the X-rays scattered from the coal. It should be noted that when determining the ash in coal, there are a number of errors due to various chemicals in the ash, the effects associated with the size of the coal granules and the effect of moisture on the coal. Determination of ash content in coal was carried out using a microprocessor-controlled 256-channel, proportional detector XRF 123-1 analyzer made in the Czech Republic.

The radioisotope of plutonium-238 (Pu-238) with an activity of 10 mCi was used as the source of activity. The size of coal samples measured by XRF 123-1 spectrometer was about 10 grams, the size of coal granules was about 3 mm, the moisture content of coal was 30%, and the experimental time was 500 seconds.

To determine the amount of ash (Ad) in coal samples, fluorescence radiations of the elements Ca (calcium), Fe (iron) and radiation scattered by the source of plutonium-238 (238-Pu) were measured. The empirical coefficient method was used to reduce the matrix effect caused by the influence of interacting elements, such as Fe and Ca. Based on the verification of equations of different calibers, the following equation (1) was chosen by the results to more accurately determine the amount of ash (Ad) in coal.

$$(Ad) = a0 + a1P\,(Ca) / P\,(BS\text{-}Pu) + a2P\,(Fe) / P\,(BS\text{-}Pu) + a3 / P\,(BS\text{-}Pu) \quad (1)$$

Where: P (Ca), P (Fe) are the peak areas of Ca and Fe, P (BS-Pu), the area of the peak scattered by Pu-238 , a0 ...... a3, - empirical coefficients.

The net areas of Ca, Fe, and peaks scattered by Pu-238 were calculated by the integration of simple peaks. For this purpose, a calibration program called "Sn" was developed according to the GW-Basic algorithm. With the help of this program, first the empirical coefficients were calculated, and then the chemical and XRF results of coal ash were compared. Table 1 shows the comparison of the ash content of coal determined by the XRF method with the results determined by the chemical method.

According to X-ray fluorescence, the ash content in coal ranged from Ad = 9.05–18.95%. The standard deviation between the chemical and XRF results is S1 = 0.748%.

The standard deviation was calculated by the following formula:

$$S1 = \frac{\sqrt{\sum_{i=1}^{N}\left(C_{XRF} - C_{Chem}\right)}}{N-1} \quad (2)$$

*Table 1. Chemical and XRF results of ash in coal samples and comparison of results*

| No | Code | Ad %, Chem. | Ad %, XRF | Delta δ |
|---|---|---|---|---|
| 1 | 20 | 16.26 | 15.80 | -0.46 |
| 2 | 21 | 14.81 | 15.48 | 0.67 |
| 3 | 22 | 16.60 | 16.62 | 0.02 |
| 4 | 23 | 18.95 | 18.29 | -0.66 |
| 5 | 24 | 11.96 | 11.93 | -0.03 |
| 6 | 25 | 12.53 | 13.30 | 0.77 |
| 7 | 26 | 12.93 | 13.41 | 0.48 |
| 8 | 27 | 11.10 | 11.05 | -0.05 |
| 9 | 28 | 13.17 | 11.56 | -1.61 |
| 10 | 29 | 11.11 | 11.46 | 0.35 |
| 11 | 30 | 11.99 | 11.69 | -0.30 |
| 12 | 31 | 10.61 | 12.13 | 1.52 |
| 13 | 32 | 13.94 | 13.85 | -0.09 |
| 14 | 33 | 11.95 | 11.89 | -0.06 |
| 15 | 34 | 10.62 | 11.12 | 0.50 |
| 16 | 35 | 10.49 | 10.62 | 0.13 |
| 17 | 36 | 11.77 | 10.32 | -1.45 |
| 18 | 37 | 9.05 | 9.33 | 0.28 |

**Conclusion**

In this study, we showed that isotope X-ray fluorescence method is one of the methods of nuclear physics, where it can quickly and accurately determine the amount of ash in coal, thereby predicting the quality of coal before burning it. For this purpose, we are convinced that the XRF 123-1 analyzer made in the Czech Republic will be an indispensable tool. The ash content in the coal samples determined by the XRF method ranged from Ad = 9.05–18.95%. The amount of chemically determined ash in these coal samples and the standard deviation between its XRF results are S1 = 0.748%. In Kazakhstan, which is rich in coal, it is possible to make a preliminary assessment of the quality of coal in coal mines by using such portable lightweight XRF analyzers, which can be carried by hand, weighing only 10 kg, thus determining the economic efficiency of coal as a fuel. We conclude that it can be an effective approach.

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