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STUDY OF THE CORRELATION BETWEEN THE COAL CALORIFIC VALUE AND COAL ASH CONTENT USING X-RAY FLUORESCENCE ANALYSIS

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Применение рентгено-флуоресцентного метода анализа
для изучения зависимости между теплотворной способностью угля
и его зольностью

В данной работе изучена возможность определения отдельных химических элементов в образцах угля с применением рентгено-флуоресцентного метода анализа и найдена зависимость между теплотворной способностью угля и его зольностью с учетом влажности угля. Количество угольной золы может быть определено по содержанию основных химических элементов, входящих в ее состав, таких как Si, Sr, Fe и Ca. Сделан вывод о том, что теплотворная способность угля может быть оценена по содержанию золы в угле без использования дополнительных калориметрических измерений. Рассчитаны коэффициенты данных корреляционных зависимостей для нескольких угольных месторождений Монголии. Полученные результаты хорошо согласуются с результатами химического анализа.

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Study of the correlation between the coal calorific value and
coal ash content using X-ray fluorescence analysis

In this paper we have studied the possibility of determining the chemical elements in coal samples using X-ray fluorescence analysis and have found a relationship between the coal calorific value and its ash content with the coal moisture accounting. The amount of coal ash can be determined by the content of the basic chemical elements, such as Si, Sr, Fe, and Ca. It was concluded that the calorific value of coal can be estimated from the ash content in coal without the calorimetric measurements. These correlation coefficients were calculated for several coal mines in Mongolia. The results are in good agreement with the results of chemical analysis.

The investigation has been performed at the Flerov Laboratory of Nuclear Reactions, JINR.

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INTRODUCTION

Coal is the main fuel for power generation in Mongolia. The quality of coal is determined by ash and moisture content in coal and its calorific value. An important characteristic for the quality and price of coal is ash content in coal. Nowadays the old chemical technique is used in the power stations for determination of ash content [1]. Conventional chemical analysis for elemental content determination requires large sequential procedures and takes time. Simple and rapid determination of coal quality is getting necessary for online technology control in power plants.

Rapid determination of coal quality will be more important since Mongolia is starting to export coal to China. Based on those requirements, study of rapid determination of coal quality, namely, determination of the ash content and calorific value in the coal samples of the mine and electric power station laboratories, has turned out more important in the last years.

Nuclear physics techniques for determination of coal quality have been used more often in the last years abroad [2]. Once developed, nuclear techniques allow not only making evaluation of the coal mine by sampling, but also determining coal quality even in boreholes.

1. DETERMINATION METHOD OF COAL ASH BY XRF

The main elements for determination of coal ash content in the samples from the Baganuur, Tavantolgoi, Shariin gol and Shivee-Ovoo coal mines by X-ray fluorescence spectrometer are described. The spectrometry contains silicon drift detector (SDD) and X-ray tube with Mo target. Measuring time was 300 s. For this study, IAEA 1632b, 2682a, 2684a and 2685a standards and AXIL software for data processing were used.

Samples were prepared by pressing into 24 mm diameter polymer container with Mylar bottom. XRF spectrum for sample is shown in Fig. 1.

It was considered that the background standard method was sufficient for determination of chemical elements content in the coal [4–6]. In Table 1, concentration ranges and average concentration of some elements are shown.

From Table 1 it is concluded that the contents of such elements as Sr, Fe and Ca are primarily responsible for determination of coal ash content.

The X-ray fluorescence technique for determination of ash content in the coal is based on measurement of intensity of fluorescent X ray of nonburning chemical elements and scattered X ray in the coal [2].

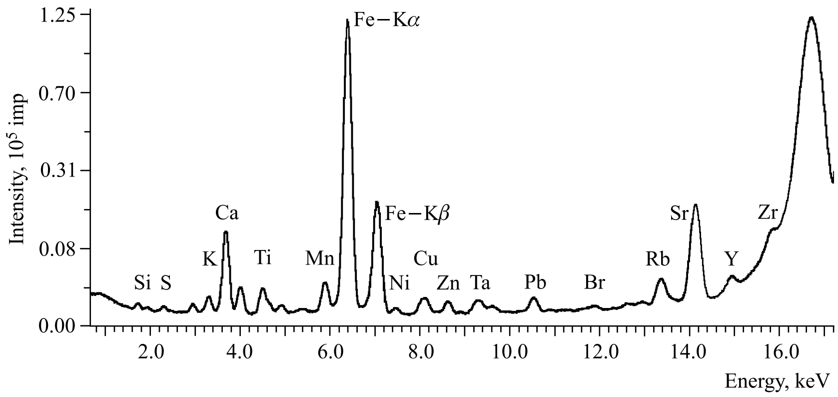

Fig. 1. XRF spectrum of coal sample

Table 1. Concentration ranges and average concentration of some elements in the coal samples

Name of coal mine		Ca, %	Fe, %	Cu, ppm	Rb, ppm	Sr, ppm	Pb, ppm
Tavantolgoi	min	0.28 ± 0.09	0.39 ± 0.01	3 ± 1	3 ± 1	60 ± 3	3.1 ± 1
	max	1.14 ± 0.35	9.8 ± 0.05	14 ± 3	26 ± 4	562 ± 12	12.1 ± 3
	average	0.38	1.63	8	11	165	7
Shariin gol	min	0.21 ± 0.08	0.14 ± 0.01	4 ± 1	6 ± 1	52 ± 3	5 ± 1
	max	1.76 ± 0.45	1.47 ± 0.02	9 ± 2	31 ± 7	294 ± 7	12.9 ± 3
	average	0.49	0.68	7	18	129	8
Baganuur	min	0.96 ± 0.26	0.78 ± 0.01	—	7 ± 1	98 ± 3	4 ± 1
	max	1.99 ± 0.59	1.62 ± 0.02	—	27 ± 4	171 ± 5	12 ± 3
	average	1.39	1.39	—	15	136	7
Shivee-Ovoo	min	1.40 ± 0.41	0.37 ± 0.01	—	4 ± 1	123 ± 3	3 ± 1
	max	2.38 ± 0.73	1.50 ± 0.02	—	12 ± 2	194 ± 5	9 ± 2
	average	1.93	0.79	—	8	153	4

The ash content can be determined by the following regression equation:

$$A_{\text{ash}} = a_0 + a_1 I_1 + a_2 I_2 + a_3 I_3 + \ldots + a_i I_i, \qquad (1)$$

where A_{ash} is ash content; A_i is coefficient determined during calibration procedure; I_i is radiation intensity measured in I window.

The constant coefficients in Eq. (1) can be determined using the well-known coal samples. Calibration should be done for each mine, as the chemical composition and calorific value are different from mine to mine.

X-ray fluorescence spectrum for coal ash determination, using the XRF spectrometer with Si(Li) detector, is shown in Fig. 2.

The results of ash determination using the XRF analyzer are compared with chemical analysis in Fig. 3. Chemical analysis by standard method was conducted at the certified Chemical Analysis Laboratory of the IV Thermal Power Plant, Ulaanbaatar.

As seen from this figure, the results of determination of coal ash content by XRF technique fit well the results of conventional methods. Average standard deviation of results of determination of ash content in the coal by XRF technique from the results of chemical analysis is 0.6% in the range of 11–26% ash.

Results of error calculation are

$$t = 1.44 < t_{\mathrm{tab}}(0.05; 47) = 2.011.$$

They show that this technique can be used for coal ash analysis.

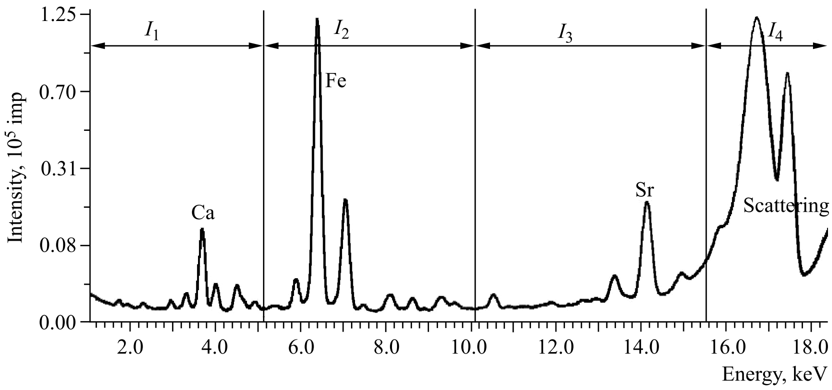

Fig. 2. Four divided X-ray spectrum for coal ash determination

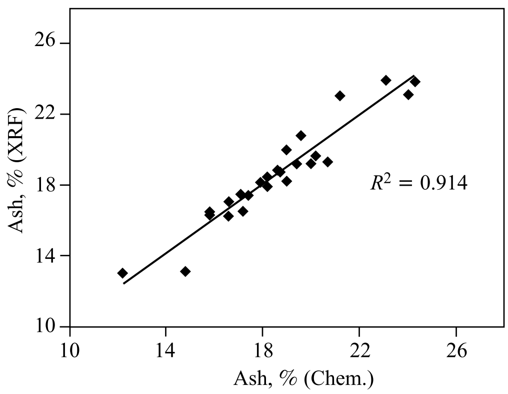

Fig. 3. Comparison of ash contents determined by XRF technique and conventional techniques

2. DETERMINATION OF CALORIFIC VALUE OF COAL BY LINEAR EQUATION METHOD

In this section we aimed to verify a method for determination of coal calorific value using other quality parameters such as moisture and ash content data.

In Table 2, coal quality characteristics of the Shariin gol, Tavantolgoi, Shivee-Ovoo and Baganuur coal mines, such as moisture (W_p), the ash content (A_p), the volatile matter (V_r), calorific value (Q_p), determined by the chemical method, are shown [1].

Table 2. Coal quality characteristics of the four coal mines

Name of coal mine	W_p, %	A_p, %	V_r, %	Q_p, kcal/kg
Tavantolgoi	8	15	28	4900
Shariin gol	18	23	45	4000
Baganuur	36	12	41	3330
Shivee-Ovoo	42	9	41	3000

If we have a certain correlation among ash content, moisture and the calorific value, then we can determine the calorific value directly from the coal ash and moisture content [2]. The calorific value of coal has a linear dependence on the ash content in coal. Results of determination of the calorific value by the correlation method fitted well at the medium moisture samples, but the error was bigger in the case of smaller moisture and bigger than medium moisture samples [2]. According to this situation, we have to consider moisture data for determination of the calorific value by the correlation method. Figure 4 shows a relation between the quantity of thermal loss by evaporation of moisture and the moisture content in the coal.

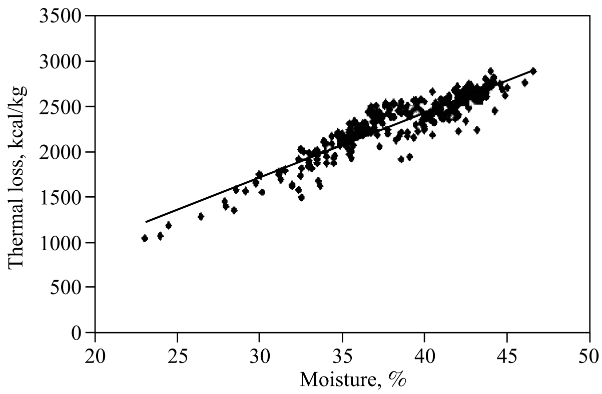

Fig. 4. Relation between the moisture content and thermal loss quantity of coal

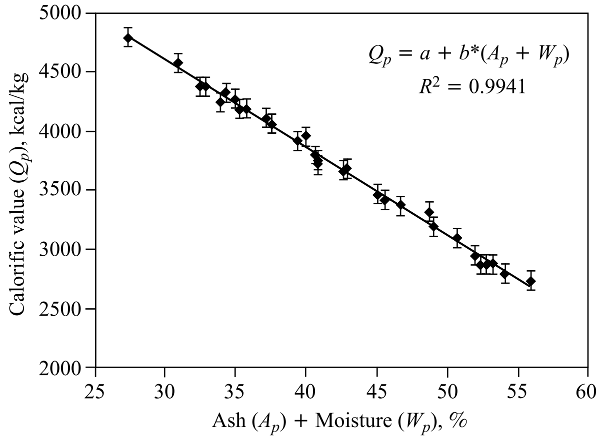

Fig. 5. Correlation between the calorific value and the sum of coal ash and moisture by reference coal samples

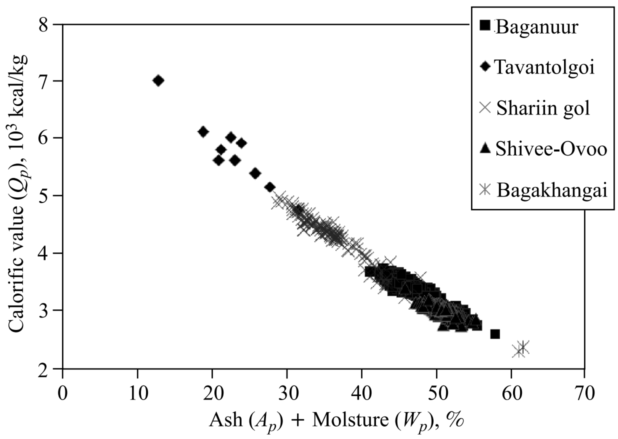

Fig. 6. Comparison of correlations of the calorific value and the sum of ash and moisture content in coal for Baganuur, Tavantolgoi, Shariin gol, Shivee-Ovoo and Bagakhangai coal mines

This means that the calorific value is also dependent on the moisture content, which is shown in Fig. 4. Correlation between the ash content and the calorific value considering the contribution of moisture is shown in Fig. 5.

The calorific values of the coal samples were determined from the ash content data using the formula

$$Q_p = a + bX, \tag{2}$$

where Q_p is the calorific value of coal; X is the sum of ash and moisture content in the coal; a, b are constant coefficients determined using well-known ash and calorific value samples.

Correlation between the calorific value and the sum of ash and moisture content in coal is shown in Fig. 6 for Baganuur (two coal mines), Tavantolgoi, Shariin gol, Shivee-Ovoo and Bagakhangai coal mines.

Thus, the calorific value of coal can be determined using the coal ash and moisture data by calculation, avoiding the calorimeter measurement for lignite and black coal mines of Mongolia.

CONSLUSION

The described new XRF analysis method for determination of coal ash content using X-ray fluorescence spectrometry with semiconductor detector can be used for determination of coal ash content in industry.

Interdependence of coal quality parameters, like coal ash, calorific value and moisture, was analyzed and it was shown that the calorific value has a linear dependence on the sum of coal ash and moisture content for same mine. A calorific value determination equation was developed using coal ash and moisture data.

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