

# The Content of Tailings Resulted from Fuel Inhibitor of the Combustion Process

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*The paper presents the interaction between the combustible mass and the tailings in the combustion process and its effect on reducing caloric power of the mass fuel. It also discusses problems regarding the influence of tailings on analytical determinations carried out on the combustible mass. Research has shown that a high content of tailings (over 25%) makes fuel inefficient, and it can only be used when combined with their organic and inorganic mass. As preparation of fuel is expensive, and very often uneconomic, we suggest that it be operated so as the content of tailings be the one required by users.*

*Keywords: combustible, tailings, waste, coal, combustion inhibition when tailings are used*

Coal is a complex of organic mass, tailings and water, elements that are chemically and physically bonded, whose separation into pure individuals is not possible, since it entails the destruction of the very physical and chemical structure of the material.

Genetically, tailings, i.e. the mineral substance contained by coal, is divided into two major categories, namely: inherent tailings, existing in the very genetic material, and adventitious, which is deposited from the outside over the coal deposit [2].

Inherent tailings, the mineral mass existing in plants, are small amounts which do not exceed a few percents and which are not separable otherwise than by the help of some chemical factors that can destroy the very structure of coal.

The main problem in the combustion process is the adventitious tailings, which represents 30-50% of the dry mass extracted from the deposit. Coal can be considered a rock in which the organic mass is over predominant, and which should be considered in the process of combustion.

The main minerals associated with coal [2, 5] are: clays, carbonates, chlorides, quartz, sulfur, etc.

*Endothermic effects caused by the transformations undergone by tailings, in the burning process*

If we look at coal, in general, we should note the high content of clay associated with adventitious tailings; they [2] are reflected in the average oxide compositions presented in table 1.

Hence, it appears that the analysis for determining the oxide composition of inorganic mass, in general, and the ash resulted from the combustion of coal, in particular, can not exactly assess the behaviour of the inorganic mass of coal in combustion, so much the more, the ash composition can only be indicative to the tailings composition. Ash is the result of transformation resulted from charring of inorganic mass. It is not the same in quantity and quality with the tailings existing prior to the combustion process.

Research of tailings behaviour in the combustion process can provide the data necessary for correct use of coal in power stations.

Table 2 shows the quantitative thermal effects of the main components and of clays, as well, when heated in oxidizing environment.

If we correlate data in table 2 with the fact that a 40-45% coal ash, which corresponds to a content of about

Component	Kaolinite	Montmorillonite	Illite
Water eliminated over 100°C	12.93	6.18	7.05
SiO <sub>2</sub>	46.65	60.80	56.17
Al <sub>2</sub> O <sub>3</sub>	38.83	22.19	19.75
Fe <sub>2</sub> O <sub>3</sub>	0.59	4.10	5.22
TiO <sub>2</sub>	0.10	0.22	0.97
CaO	0.11	0.28	2.87
MgO	0.39	2.78	1.87
K <sub>2</sub> O	0.29	0.11	4.46
Na <sub>2</sub> O	0.10	2.17	0.61
SO <sub>2</sub>	0.17	0.74	1.37

**Table 1**  
THE AVERAGE OXIDE COMPOSITION OF  
MAIN TYPES OF CLAY ASSOCIATED WITH  
COAL [2]

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Current Number	Specification	Unit	Kaolinite	Montmorinollite	Illite
1.	Heat for elimination of crystallisation water in vapour state	kcal/kg component	+186.0	+58.5	+43.2
2.	Heat for elimination of hydration water	kcal/kg component	+75.8	+36.1	+41.3
3.	Quartz exothermal effect	kcal/kg component	- 47.6	-40.3	-36.6
4.	Correlation of exothermal effect of potassium, natrium, calcium, magnesium silicates	kcal/kg component	+2.6	+21.2	+35.1
5.	Total thermal effect	kcal/kg component	+216.8	+75.5	+83.0

**Table 2**  
THERMAL EFFECTS APPEARING WHEN MINERALS, COMPONENTS OF CLAYS, ARE HEATED [4]

15% more tailings, kaolinite would represent 60% of it; for one kilogram of coal there will be 0.47 to 0.53 kg tailings, which means 0.282 to 0.318 kg kaolinite. This means that only for the thermal transformation of kaolinite [3,4] it would take an absorption of 46-48 kcal/kg of coal.

Thermal behaviour of some types of clays in Romania shows two main endothermal effects, one between 100 and 200 °C, and another one between 500 and 600 °C.

If we admitted that clays would represent approx. 60% of tailings it is also necessary to present thermal transformations of other minerals associated with coal, which in their totality could form the other 40% of the tailings.

In quartz we can notice the existence of exothermal effects, between 100 and 200°C, for tridymite, and between 200 and 300°C, for cristobalite. Simple quartz presents only a small endotherm between 500 and 600 °C [4, 5].

Other types of compounds that give strong endothermic effects are carbonates, silicates and sometimes hydroxides. The major components of this type that occur in coal are calcium, magnesium, iron, iron hydroxids, and aluminum silicates.

Thermal effects of thermal transformation reactions of the substances mentioned above are presented in fable 3.

If carbonates represented 20% of tailings composition, for coal with 40-45% ash, i.e. 47-53% tailings, coal will contain carbonate mixtures in proportion of 20%.

For 1 kg of coal there would result 0.470 - 0.530 kg tailings, so 0.094 - 0.105 kg of carbonates, which at an average endothermic effect of 350 kcal/kg, would produce endothermic effects of 32-36 kcal / kg coal.

#### Other Minerals Found in Coal

Most minerals found in coal give endothermic effects below 900°C [4, 5].

Research highlights the multitude of endothermic effects by which these minerals contribute to thermal balance of coal combustion. Considering that, besides clay and carbonates, the remaining minerals represented 20% of coal tailings, we could notice that these would lead to a total endothermic effect of about 20-25 kcal / kg.

#### Endothermic Effects of Coal Tailings

Table 4 presents an analysis of the endothermic effects due to tailings for coal with 40 -45% ash, i.e. with a content of tailings increased by about 15 % ( 47-53 %).

The above show that the total endothermic effect of minerals contained in coal may rise to the level of 98-129 kcal / kg coal, so it can have a great influence in calorific power calculations.

In calculating the lower calorific value we should take into account the fact that most minerals associated with coal emit water, between 300-600° C, which represents approximately 10% of the respective mineral, i.e. 0.047 to 0.053 kg / kg of fuel, which, in turn, could lead to decreases by 28-32 kcal / kg of lower calorific power value.

It follows that, in case of high calorific power, the tailings contribute with an endothermic effect of 98-129 kcal / kg; in case of lower calorific power, it contributes with an endothermic effect of 126-160 kcal/kg. This, for a lower calorific power of 1000 kcal/kg, represents a decrease of 12.6 - 16 % .

Substance	Formula	Reaction	Thermal effect	
			kcal/kmol	kcal/ kg
Chalk	CaCO <sub>3</sub>	CaCO <sub>3</sub> – CAO + CO <sub>2</sub>	42520	425.2
Magnesium carbonate	MgCO <sub>3</sub>	MgCO <sub>3</sub> – MgO + CO <sub>2</sub>	27360	325.7
Iron carbonate	FeCO <sub>3</sub>	FeCO <sub>3</sub> – FeO + CO <sub>2</sub>	26770	230.7
Iron hydroxide	Fe(OH) <sub>3</sub>	2Fe(OH) <sub>3</sub> - Fe <sub>2</sub> O <sub>3</sub> + 3H <sub>2</sub> O	26140	122.1
Hydrated aluminum silicates	AlO <sub>3</sub> . 2SiO <sub>2</sub> . 2H <sub>2</sub> O	AlO <sub>3</sub> . 2Si O <sub>2</sub> . 2H <sub>2</sub> O - AlO <sub>3</sub> . 2Si O <sub>2</sub> + 2H <sub>2</sub> O	39600	153.4

**Table 3**  
THERMAL EFFECTS OF TRANSFORMATIONS OF SOME CARBONATES AND SILICATES; CARBONATES AND SILICATES ARE MINERALS ASSOCIATED TO COAL [4]

Current Number	Specification	Units	Values	Observations
1.	Ash content	% kg/kg coal	40 - 45 0.4 – 0.45	
2.	Tailings content	% kg/kg coal	47 - 53 0.47 – 0.53	Approx. 15% more than the ash content
3.	Carbonates	% kg/kg coal	60 0.282 – 0.318	
		% kg/kg coal	20 0.094 – 0.106	
4.	Other minerals	% kg/kg coal	20 0.094 – 0.106	
5.	Kaolin	kcal/kg	216	Values for 1kg of mineral
	Carbonates	kcal/kg	350	
	Other minerals	kcal/kg	350	
6.	Kaolin	kcal/kg	46 – 48	Values for 1kg of coal
	Carbonates	kcal/kg	32 – 36	
	Other minerals	kcal/kg	20 - 25	
7.	Total possible endothermic effect for 1kg of coal	kcal/kg	98 - 109	

**Table 4**  
TOTAL ENDOTHERMIC EFFECTS FOR COAL WITH 40-45 % ASH [5]

Sample	Dampness	Ash	Volatile matters	Carbon	Hydrogen	Sulphur	(Oxygen + Azote) <sup>a</sup>
	W <sup>a</sup>	A <sup>a</sup>	V <sup>a</sup>	C <sup>a</sup>	H <sup>a</sup>	S <sup>a</sup>	(O <sub>2</sub> +N <sub>2</sub> ) <sup>a</sup>
	%	%	%	%	%	%	%
Lonea	2.98	53.35	28.29	30.26	0.88	2.05	10.48
Petrila	3.25	53.14	27.32	31.55	0.81	2.39	8.86
Vulcan	3.07	51.25	26.25	33.14	0.76	2.11	9.67
Aninoasa	3.02	50.34	26.05	33.26	0.78	1.91	10.69

$$100=W^a + A^a + C^a + H^a + S^a + (O_2+N_2)^a$$

*Experimental Study on the Inhibitory Effect of the Combustion Process Carried out on Samples with 70-75% Tailing Content Separated from Romanian Pit Coal.*

#### Equipment and working

The research was conducted on samples from the Jiu Valley energetic coal samples (from Lonea, Petrila, Aninoasa and Vulcan mines), with about 70% tailing content, separated by hand picking, which was expected to be used as fuel. Analyses were performed according to standardized Romanian norms, i.e. STAS and ISO (state – imposed standards, and IOS respectively).

#### Results and discussions

Characteristics of the studied samples according to standards and ISO norms are presented in table 5.

Current Number	Sample	Clays	Quartz	Carbonates	Sulphides
		Related to initial coal sample			
		%	%	%	%
1	Lonea	37.90	10.24	21.01	3.55
2	Petrila	38.65	11.15	20.14	3.84
3	Vulcan	36.14	12.12	20.11	4.11
4	Aninoasa	35.21	11.37	22.20	3.91

**Table 6**  
CLAYS, QUARTZ, CARBONATES AND SULPHIDES OF ANALYSED COAL SAMPLES

The test results are wrong because of:  
- water resulted from clays, at 450-500° C - it changes the volatile substances and the content of hydrogen and carbon;  
- CO<sub>2</sub> from carbonates, changes the volatile substances and the content of carbon.

Determination of clay and quartz carbonates from samples was performed by absorption spectroscopy in infrared environment; the results were compared to the spectra of alumina and clay mixtures, or alumina and quartz. Carbonates were determined by granulometric dosing of CO<sub>2</sub> emitted [1]. The results are presented in table 6.

Current Number	Sample	Carbon	Hydrogen	Sulfur
		C <sup>mc</sup>	H <sup>mc</sup>	S <sup>mc</sup>
		%	%	%
1	Lonea	* 30.26	0.88	1.70
		** 38.01	0.81	3.20
2	Petrila	31.55	0.81	2.39
		28.14	0.72	3.89
3	Vulcan	33.14	0.76	2.11
		30.12	0.86	3.76
4	Aninoasa	33.26	0.78	1.91
		30.22	0.97	3.54

**Table 7**  
COMPARATIVE RESULTS OF COALS UNDER OBSERVATION, DETERMINED THROUGH CLASSICAL METHODS, AND TAKING INTO ACCOUNT THE COMPOSITION OF THE TAILINGS

\*Standard Analysis

\*\*Analysis regarding tailings content

Sample	Clays		Carbonates		Quartz		Total
	kg/kg comb.	kcal/kg comb.	kg/kg comb.	kcal/kg comb.	kg/kg comb.	kcal/kg comb.	kcal/kg comb.
Lonea	0.3790	59	0.2101	84	0.1024	-	143
Petrila	0.3865	60	0.2014	85	0.1115	-	145
Vulcan	0.3614	57	0.2011	84	0.1212	-	141
Aninoasa	0.2521	39	0.2230	89	0.1137	-	128

**Table 8**  
THERMAL EFFECTS OF TAILING TRANSFORMATIONS

Comparative analysis was conducted according to state – imposed standards, and to tailings components dosages. The results are presented in table 7.

Carbon decreases; hydrogen increases; sulfur increases.

Calculation of heat taken over by tailings transformations are presented in table 8.

In general, the thermal effect of changes taking place in coal with high content of tailings are between 100 and 150 kcal / kg.

If we analyse the tables presented (1-8) we notice that the classical methods of standard analysis can be used only for fuels with a lower than 20% percentage of tailings. A higher content of tailings significantly changes, by decreasing, the analytical characteristics of the material.

Tailings has inhibitory properties for combustion, reducing significantly the calorific value of the material.

Tailings show aspects related to the structure of coal, to its placing within the category of bituminous coals due to the presence of false hydrogen in elementary analysis, caused by water that is released from clays at 450-500° C.

Tailings show lower values for the combustion mass of coal due to transformations in the minerals contained by tailings.

## Conclusions

Tailings inhibit combustion.

Tailings, most of the times, are unnecessary consumers of the fuel energy.

Tailings influence in a negative way the calculation of combustion plants capacity.

The use of fuels with high content of tailings is recommended only for processes which principally use tailings, i.e. clinker, etc. It is not recommendable to use it in other processes, since it proved to be disadvantageous.

It is necessary to standardize the analytical method for fuel with high content of tailings.

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