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Peter Fecko, Iva Pectova*, Vladimir Cablik*,*
Silvie Riedlova, Pavla Ovcari*, Barbara Tora***

BACTERIAL DESULPHURIZATION OF COAL

1. Introduction

Desulphurization of the fuels is a problem, which even with big effort of humans beings it has not been solved so as to the stop SO_2 introduction to air. It is well known that the high amount of sulphur in coal has adverse influence on its utilization and that contributes to environment contamination as the acid rain [2–4]. There are more evidences that the Czech Republic occupies one of the first positions in Europe in environment contamination by sulphur oxides, because our main source of energy is the combustion of solids fuels. In the amount of industrial emissions per km^2 the Czech Republic is second in the world (25 t/km^2) and in the amount of emissions per inhabitant is third (0.2 t). Combustion depends on the concentration of sulphur which reaches somewere around 12%.

2. Materials and Methods

2.1. Distribution of sulphur in coal

Sulphur is presented in its organic and inorganic forms in coal. Free sulphur is presented only sporadically. Pyrite and marcasite are presented in large quantities but their proportions vary. Sulphates, mainly gypsum, originated primarily during the carbonisation process and secondarily during the weathering of pyrites. Organic sulphur is mainly bound to the structures of dibenzenethiophene, benzenethiophene and thiols. Pyrite is presented in the epigenetic and syngenetic forms. Syngenetic pyrite was formed during the first phase of the coal forming process and that is, why it is interspersed within the coal substance. Epigenetic pyrite is geolo-

* VSB TU — Mining University of Ostrava
** Wydział Górnictwa i Geoinżynierii, Akademia Górniczo-Hutnicza, Kraków

gically younger, therefore it acts as a filling material in the joints and fissures. It is less intergrown within the coal substance, it forms larger crystals and is easier to eliminate by suitable coal processing methods. A whole range of chemical techniques with the potential to separate pyrite from coal was reviewed, and also some microbiology techniques. The chemical techniques for desulphurization employ relatively non-specific reactions, functioning at high temperatures and pressures, and with relatively high consumption of chemicals. The methods of microbiology have the advantage of very specific reactions in a simple reactor, at ambient temperature and normal pressure, but they need a longer leaching time. The aim of this work is confirmation the viability of bacterial leaching applications on the samples of black coal from the different localities [2–4].

2.2. *Thiobacillus ferrooxidans*

They are aerobic, chemoautotrophic organisms that require atmospheric oxygen and inorganic compounds with CO_2 for production of their new biomass. They are non-sporulating gram negative bacteria. In appearance they are sticks of average 0.5-0.8 μm with length 0.9-1.5 μm. *Thiobacillus ferrooxidans* can get energy by oxidation of sulphur components and by oxidation of Fe^{2+}. Optimal temperature for this bacteria is: 28-30°C and optimal pH is n the range 1.8-2.2 [5].

Principle of pyrite oxidation by *Thiobacillus ferrooxidans* bacteria

Bacterial leaching can be either direct or indirect. In the direct interaction the surface of the minerals is occupied by bacteria and metal sulphides are attacked by enzymatic oxidation.

Direct leaching oxidation of pyrite is best described by the following equations:

$$FeS_2 + 3{,}5\ O_2 + H_2O \rightarrow FeSO_4 + H_2SO_4$$

$$2\ FeSO_4 + 0{,}5\ O_2 + H_2SO_4 \rightarrow Fe_2\,(SO_4)_3 + H_2O$$

The bacteria create a leaching agent in indirect bacterial leaching. This agent oxidises sulphidic minerals. In acid solutions Fe^{3+} is the active agent. The solubility of pyrite can be written as:

$$Fe_2\,(SO_4)_3 + FeS_2 \rightarrow 3\ FeSO_4 + 2S^0$$

$$2S^0 + 3O_2 + 2\ H_2O \rightarrow 2\ H_2SO_4$$

2.3. Methods of bacterial leaching

For the bacterial leaching testwork a 10-litre airlift glass bioreactor patterned on the research of Deutsche Montan Technologie Company – Essen. [1] was used. After sterilization of the reactor, the prepared samples of coal were placed in it together with the medium 9K without $FeSO_4$. After one hour of mixing and homogenising of the suspension, 1,000 ml of the bacterial culture *Thiobacillus ferrooxidans* was introduced into the reactor. Clean bacterial cultures of *Thiobacillus ferrooxidans* from the Czech-Slovak Collection of Micro-organisms in Brno were used for the test programme. The concentration of introduced bacteria in the process was 10^9 in 1 ml bacterial solution. The bioreactor was connected to the aquarium water aerator, which supplied the reactor with air. The air was cleaned in washers in 1 M H_2SO_4 solution to have more moisture and to remove airborne bacteria. Mixing of 5% suspension was using air. pH was measured by laboratory pH-meter "RADELKIS" and the pH was kept at the optimal value 1,8-2 during the whole experiment (28 days) to prevent formation of unwanted jarosite. The temperature was kept in the range 26-30°C during the whole experiment. During the leaching, after 1, 2, 3, and 4 weeks, samples of approximately 50 ml were taken from the bioreactor for analysis. A part of each sample was used for measuring the biomass growth by MPN method, and the rest was filtered on a Buchner funnel where the filtrate and the filter cake were separated, Fe^{2+} was determined in the filtrate by titration, and the content of total sulphur and its separate forms were determined in the filter cake. The cake was washed in 100 ml of 1M HCl and in 200 ml distilled water before the determination. [1]

2.4. Petrographic analysis

Measurement condition

Maceral analysis was performed on the grains according to CSN ISO 7404-2 and 7404-3 using a Zeiss NU-2 microscope. Planimetric analysis was evaluated in oil immersion, with refractive index n_D = 1,515, and the length wave λ = 546 nm, temperature t = 20°C, objective enlargement 32x.

2.5. Determination of sulphur

Sulphur was determined at the Research Coal Institute in Ostrava Radvanice on a LECO SC 132 instrument, directed by microprocessor with detection of SO_2 using infrared detector. Different forms of sulphur were determined by thermal phase analyses at temperatures 420°C (organic sulphur) 820°C (pyrite sulphur) and 1,370°C (total sulphur) with constant programme conditions. The sulphate sulphur was calculated.

3. Results of bacterial leaching and mineralogical-petrological analysis and discussion

3.1. Coal sample from Mine Darkov

Maceral group of vitrinite was represented mainly by small collinite grains. Collinite was part of trimacerite, clarite and vitrinertite. Telinite was less abundant. In this sample light oxidative edges on the collinite grains were not registered. Percentage of this group was 71.2% including undertermined mineral, and at recounting to clean coal mass 77.0%.

The group of liptinite was represented mainly by microsporinite. The cutinite was less bountiful. The occurence of rezinite and macrosporinite was rare. These macerals were included in durite, trimacerite and clarite. Percentage of this group was approximately same at calculation including coal mass even without it 5.1% resp. 5.6%.

The group of inertinite was very abundant. It was created mainly by macrinite and micrinite as part of durite, trimacerite and vitrinertite. The fusinite figured as fusite in the form of individual grains. Percentual representation of inertinite group was 16.2% including undertermined mineral and at recounting to clean coal mass increased its content to 17.5%.

Undertermined mineral was represented by clay minerals which was formed carbargilite, less as individual grains. Also the carbonates were observed – mainly siderite. The content of pyrite was not higher than 1.5%, it occured mainly as carbopyrite in massive form (Fig. 1). The occurence of non-specific inorganic mass was minimum.

The mono-maceral (vitrite, fusite), bi-maceral (more durite and vitrinertite then clarite) and trimaceral microlitotypes were represented from microlitotype view.

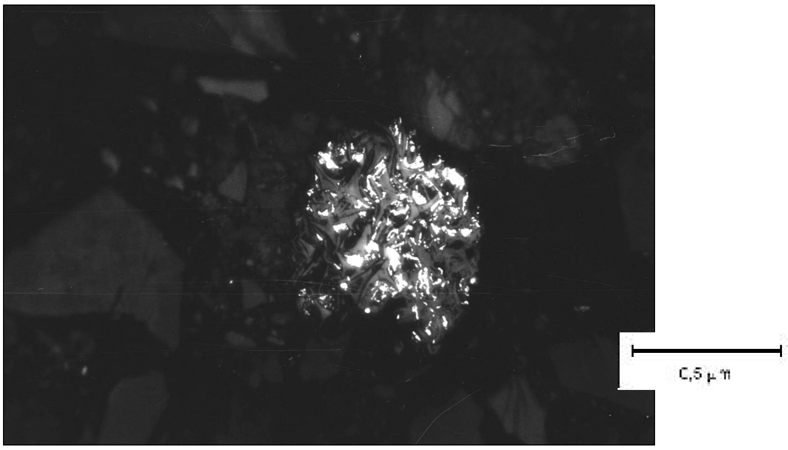

Fig. 1. Coal mass mineralized by pyrite

Results of bacterial leaching from Mine Darkov

The results of bacterial leaching are given in the Table 1 and 2. From the results of bacterial leaching followed that this sample is suitable for application of bacterial leaching, the desulphurization degree of total sulphur was 57% and desulphurization of pyritic sulphur was 75%. The suspension did not contain the bacteria after two weeks of leaching, and at the same time concentration of bacteria in 1 ml of suspension was 10^9, that testify about good adaptability of *Thiobacillus ferrooxidans* on given sample.

There is still a problem to separate organic sulphur. Because bacteria *Thiobacillus ferrooxidans* are not suitable for elimination of organic sulphur it could be possible to eliminate it by *Sulfolobulus acidocaldarius* bacteria.

TABLE 1

Results of bacterial leaching of coal from mine Darkov

Duration after leaching days	Fe^{2+}, mg/l	S_{total}, %	Amount of bacteria in 1 ml
introduction		1.12	
7	45.85	0.69	$17.\ 10^8$
14	0	0.53	$12.5.\ 10^9$
21	0	0.50	$30.\ 10^9$
28	0	0.48	$60.\ 10^9$

TABLE 2

Results of bacterial leaching

Sulphur	Before leaching, %	After leaching, %	Level of desulphurization, %
S_{total}	1.12	0.48	57.14
$S_{pyritic}$	0.55	0.14	74.55
$S_{organic}$	0.22	0.17	22.73
$S_{sulphate}$	0.35	0.17	51.43

Character of sample after leaching

Maceral group of vitrinite was again represented by small vitrinite grains, which identification was difficult. Again, light edges were seen on small collinite grains. Percentage of this groups was 73.8% including undertermined mineral, what is 77.2% at recounting to clean coal mass.

Liptinite group was represented by same way as in previous fraction 6.9% including undertermined mineral and 7.2% without it. This group is formed mainly by microsporinite, less by cutinite. Liptinite group was part of durite, clarite and trimacerite.

Maceral group of inertinite was 15%. Its content was 15.6% at recounting to clean coal mass.

This group contained fusinite forming fusite and macrinite creating durite. Also semifusite was identified, occasionaly even sclerotinite. The anorganic admixture was formed by clay minerals as well as carbonates creating with coal mass carbargilite resp. carbankerite. The pyrite occured rarely. Its content was not determined planimetrically. The fine-grained non-specific undertermined mineral was identified a few.

From microlitotypes prevailed vitrite, further durite, vitrinertite and less often clarite.

3.2. Coal sample from Mine Jankowice

Maceral group of vitrinite was represented by collinite and telinite. Vitrinite formed first basic mass of clarite and trimacerite. Percentage of this group was 77.4% including undertermined mineral what is 87.2% in clean coal mass.

Liptinite group was mainly formed by microsporinite, that was substantially more represented then macrosporinite. Sporadically there was abundant cutinite accumulation, so cutinite clarite grains were observed. Percentage of this group was 7.4% including undertermined mineral and 8.3% at recounting to clean coal mass.

Percentual representation of inertinite maceral group was very low. From this group prevailed macrinite that was part of durite or trimacerite as well as fusinite. Fine-grained micrinite filled all spaces in telinite. Percentage of inertinite group was almost same including undertermined mineral 4.0% and without it is 4.5%.The pyrite was part of undertermined mineral and it was very abundant in its framboidal form (Fig. 2). Pyrite was also occured in euhedral form (Fig. 3) or together with clay minerals as carbopolyminerite. Its percentual representation was 2.5%. The carbonates were created by siderite (Fig. 3). Clay minerals occured both in carbopolyminerite (mentioned above) and in carbargilite. Further, other mineral admixture was represented, but it was not possible to identify it microscopically. Monomaceral, bimaceral and trimaceral microlitotypes were observed from microlitotype view. There was watched: mainly clarite from trimaceral microlitotype, from monomaceral vitrinite, sporadically inertinite and quite rarely liptite.

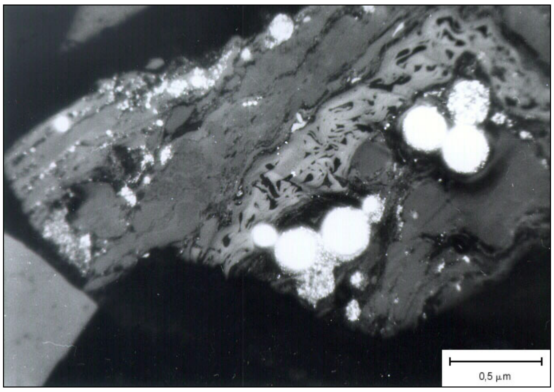

Fig. 2. Framboidal form of pyrite

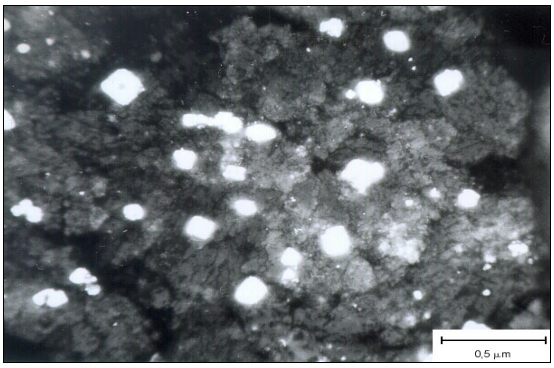

Fig. 3. Siderite with euhedral form pyrite

Results of bacterial leaching from Mine Jankowice

It is apparent from the below mentioned results (Tables 3 and 4) that following 28 days of bacterial leaching, it is possible to remove approx. 70% of pyritic sulphur and 45% of organic sulphur. Thus, total desulphurization was approx. 70%.

Coal is a suitable medium for the *Thiobacillus ferrooxidans* bacteria, which adapted well there and after 3 weeks of leaching the concentrations reached 10^9 in 1 ml of suspension and after 3-week leaching no bivalent iron is present in the sample.

TABLE 3
Results of bacterial leaching of coal from mine Jankowice

Duration after leaching days	Fe^{2+}, mg/l	S_{total}, %	Amount of bacteria in 1 ml
introduction		1.71	
7	115.20	1.19	$35. 10^8$
14	35.40	0.76	$70. 10^8$
21	–	0.57	$110. 10^9$
28	–	0.51	$225. 10^9$

TABLE 4
Results of bacterial leaching

Sulphur	Before leaching, %	After leaching, %	Level of desulphurization, %
S_{total}	1.71	0.51	70.18
$S_{pyritic}$	0.52	0.16	69.23
$S_{organic}$	0.33	0.18	45.45
$S_{sulphate}$	0.86	0.17	80.23

Character of sample after leaching

Maceral group of vitrinite was represented by leaching danaged grains, so it was very difficult to identify if it is collinite or telinite. The occurence of light oxidative edges was observed again, also around cracks. Percetage of this group was 74.0% incluing undertermined mineral. During recounting to clean coal mass its content increased to 63.0%. Vitrinite formed separate grains or it was part of individual microlititypes.

Percentage of liptinite group was 8.3% including undertermined mineral and about 1% highes at recounting to clean coal mass (9.3%). This group was mainly created by microsporinite and by cutinite contained in both trimacerite and clarite.

The inertinite group was firstly formed by heavily identified fragments. Fusinite, macrinite and micrinite was possible observe at bigg grains. Sclerotinite occured rarely. Percental representation of this group was a little higher then in previous fraction namely 6.9% including undertermined mineral and 7.8% in clean coal mass. Pyrite content again decreased, about 0.6% compated with previous sample, and in comparison with original sample it was 1.9%. Remained pyrite occured in framboidal form and its content amounted 0.6%.

Clay minerals represented by carbargilite were undertermined mineral, sometime they cencented small grains. Indeterminable inorganic mass represented a little less then in previous samples. The representation didn´t change from microlitotype view. All three microlitotype types were observed again, mainly by the leaching damaged vitrinite from monomaceral types, from bimaceral types clarite and durite as well as vitrinertite.

3.3. Coal sample from Mine Marcel

Maceral group of vitrinite was largely represented by collinite, that formed basic mass of clarite, eventualy was part of trimacerite. The telinite was also abundant. The light edges were observed at some grains in this sample, they did not occur often, they border only part of grain or cracks in some cases.

Percentage of this group was 73.8% including undertermined mineral and 77.6% at recounting to clean coal mass.

Liptinite group was essentially represented by microsporinite, cutinite, less by macrosporinite and quite occasionally by rezinite. Percentual representation of this group was 11.1%, in clean coal 11.7%.

Inertinite group showed similar percentual representation. Macrinite was very abundant. Fine grained micrinite filled cell spaces of telinite. Fusinite formed separate grains as fusite (Fig. 4). Inertinite was often part of trimacerite or durite. Percentage of this group was 10.2% including undertermined mineral and 10.7% at recounting to clean coal mass.

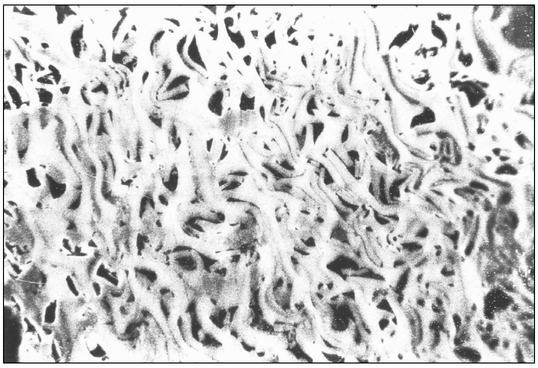

Fig. 4. Fusite

Undertermined mineral was represented by carbonates, that formed individual grains or carbominerite. Pyrite content was lower than 1.6% and occured mostly in massive form, less in euhedral or framboidal form.

Clay minerals were represented less, they created thin strips in vitrite-carbargilite. Indeterminable inorganic mass was slight. From microlitotype view dominated all three microlitotypes. It was mostly vitrite and fusite, from bimaceral types prevailed clarite (often cutinite clarite), less durite. Trimacerite grains were abundant.

Results of bacterial leaching from Mine Marcel

It is apparent from the below mentioned results (Tables 5 and 6) that following 28 days of bacterial leaching, it is possible to remove approx. 60% of pyritic sulphur and 60% of organic sulphur. Thus, total desulphurization was approx. 72%.

Coal is a suitable medium for the *Thiobacillus ferrooxidans* bacteria, which adapt well there and after 3 weeks of leaching the concentrations reached 10^9 in 1 ml of suspension and after 3-week leaching no bivalent iron is presented in the sample.

TABLE 5

Results of bacterial leaching of coal from mine Marcel

Duration after leaching days	Fe^{2+}, mg/l	S_{total}, %	Amount of bacteria in 1 ml
introduction		1.56	
7	335.10	1.21	$25.\ 10^8$
14	117.25	0.63	$160.\ 10^9$
21	75.30	0.59	$160.\ 10^9$
28		0.44	$235.\ 10^9$

TABLE 6

Results of bacterial leaching

Sulphur	Before leaching, %	After leaching, %	Level of desulphurization, %
S_{total}	1.56	0.44	71.79
$S_{pyritic}$	0.52	0.21	59.62
$S_{organic}$	0.49	0.20	59.18
$S_{sulphate}$	0.55	0.03	94.55

Character of sample after leaching

Maceral group of vitrinite was represented by small fragments of collinite or telinite. It was possible to see hole vitrinite grains, from whitch remained only “wrecks”. Again, light oxidative edges were observed at this sample, mainly at smaller collinite grains. (Fig. 5) Percentage of this group was only 70.7% inclouding undertermined mineral, at recounting to clean coal mass its content increased to 79.3%. In this fraction content of liptinite group was lower then in previous samples. This group was mainly represented by microsporinite, that was part of clarite or trimacerite. Percentage of this group was 7.4%, in clean coal mass

8.3%. Maceral group of inertinite was first created by fusinite. Very abundant was also occurrence of unidentified fragments of inertinite in clarite. Percentual representation of this group was 11.0%, including undertermined mineral that is 12.4% at recounding to clean coal mass. The undertermined mineral was created by carbonates. Clay minerals were represented by carbagilite.

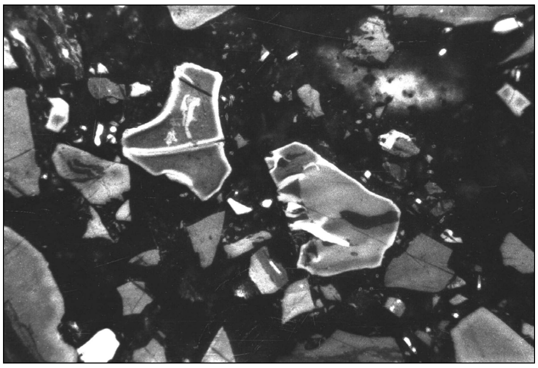

Fig. 5. Oxidative edges on smaller vitrinite grains

The content of unidentified undertermined mineral was insignificant. Pyrite content further decreased, namely to value 0.4%. From microlitotypes were again represented monomaceral, bimaceral and trimaceral types. From monomaceral, it was vitrite – strongly damaged by leaching, from bimaceral types clarite, durite and vitrinertite were observed.

3.4. Coal sample from Mine Staszic

The vitrinite maceral group was mainly represented by collinite, which formed the matrix of clarite, or it made part of trimacerite. Also, telinite often occurred. No light margins on the vitrinite grains were registered with the sample. Percentage abundance of this group was 69.7%, including inorganic foreign matter, and 73% with recalculation to clear coal mass.

Essentially, the liptinite group was represented by microsporinite. Cutinite was less frequent. In some grains, there was a great conglomeration of liptinite such extent that it transferred to liptite (Fig. 6). Percentage abundance of this group was 9.6%, in clear coal the content equalled 10%.

The inertinite group was frequent. Mainly it was formed by macrinite and micrinite, as part of durite, trimacerite or vitrinertite. Fusinite often constituted separate grains as fusite. Percentage abundance of this group was 16.2%, including inorganic foreign matter, and 16.9% with recalculation to clear coal mass.

The undertermined mineral was formed by carbonates in form of carbancerite or separate grains. Next, clay minerals were observed, which along with vitrinite provided carbargilite. The pyrite content was not high (1.7%). It occurred mainly in massiv form. The occurrence of closely unidentifiable inorganic mass was not planimetrically determined. From the microlitothype point of view there were monomaceral, bimaceral and trimaceral microlitothypes. Chiefly, these were vitrite and fusite. From the bimacerals, mainly clarite and durite, less of vitrinertite. The trimacerite grains were less frequent.

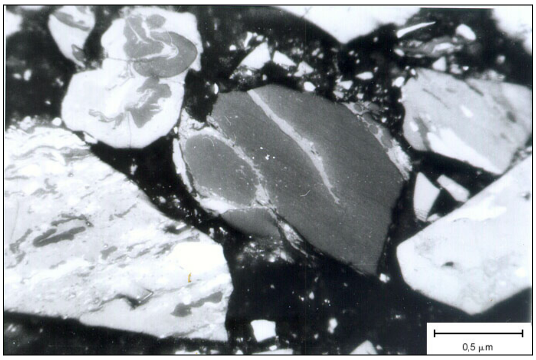

Fig. 6. Liptite

Results of bacterial leaching from Mine Staszic

It is apparent from the below mentioned results (Tables 7 and 8) that following 28 days of bacterial leaching, it is possible to remove approx. 82% of pyritic sulphur and 65% of organic sulphur. Thus, total desulphurization was approx. 46%.

TABLE 7
Results of bacterial leaching of coal from mine Staszic

Duration after leaching days	Fe^{2+}, mg/l	S_{total}, %	Amount of bacteria in 1 ml
introduction		1.45	
7	53.20	1.22	$48.\ 10^{8}$
14	15.60	1.11	$120.\ 10^{8}$
21	–	1.02	$235.\ 10^{8}$
28	–	0.78	$40.\ 10^{9}$

TABLE 8
Results of bacterial leaching

Sulphur	Before leaching, %	After leaching, %	Level of desulphurization, %
S_{total}	1.45	0.78	46.21
$S_{pyritic}$	0.33	0.06	81.82
$S_{organic}$	0.62	0.22	64.52
$S_{sulphate}$	0.5	0.5	–

Coal is a suitable medium for the *Thiobacillus ferrooxidans* bacteria, which adapt well there and after 3 weeks of leaching the concentrations reached 10^8 in 1 ml of suspension and after 3-week leaching no bivalent iron is presented in the sample.

Character of sample after leaching

The vitrinite maceral group was represented by fine fragments of collinite or telinite. Similarly to the four previous samples no light margins were intercepted on the vitrinite grains. Percentage abundance of this group was 70.7%, including inorganic foreign matter, which is 76.5% with recalculation to clear coal mass.

With this sample another fall in liptinite took place. The liptinite group was represented by mainly microsporinite, less of cutinite. Macerals of this group made part of durite primarily. Percentage abundance of this group was 6.9%, with recalculation to clear coal mass its content was higher by 0.6% (i.e.7.5%).

The inertinite maceral group abundance was 14.8%. With recalculation to clear coal mass its content was 16%. As a rule, it concerned fusinite, forming fusite and macrinite, forming durite.

The content of pyrite continued decreas. Its share in this fraction was only 0.2%, which is 1.5% less than with the previous sample. Again, it was possible to observe a decrease in the pyritic mass in favour of secondary minerals (Fig. 7). Carbonate share was represented by siderite and calcite. This sample contained a higher content of clay minerals, which along with the coal mass formed carbargilite. Closely unidentifiable fine-grained inorganic foreign matter was slightly present.

From microlitothypes there was vitrite broken by leaching, then durite, vitrinertite, less often clarite.

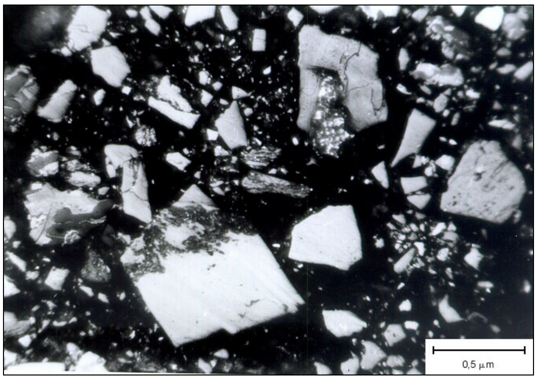

Fig. 7. Loss of pyrite mass in favour of secondary minerals

3.5. Coal sample from Mine Dukla

Maceral group of vitrinite (69.9%) was represented by collinite that embodied in some grains contraction cracks. This maceral is connected with the presence of mineral admixture.

Very abundant and obvious was a liptinite (6.2%), it deals with the coal which has higher content of volatile combustible. The liptinite was mostly represented by microsporinite and macrosporinite, in some grains accumulation of cutinite occured.

The inertinite was substituted at least only 8%. In this maceral group mostly appeared fusinite, its cell space was often filled by clay minerals and carbonates.

From the microlitotypes prevailed vitrite over clarite and durite. Trimacerite was also occured. The undertermined mineral consisted of clay minerals that filled up cell space of fusinite (likewise as siderite) as well pyrite. The pyrite filled up the cracks or formed framboids or clusters (Fig. 8).

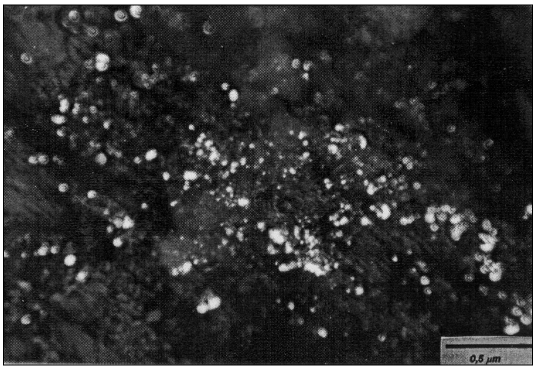

Fig. 8. Framboidal form of pyrite

Results of bacterial leaching from Mine Dukla

Still there is a problem to separate organic sulphur. Because bacterial *Thiobacillus ferrooxidans* are not suitable for elimination of organic sulphur it could be possible to eliminate by *Sulfolobulus acidocaldarius* bacteria. Desulphurization of pyritic sulphur was about 77% and total desulphurizatrion was about 38%. The results of bacterial leaching are in Tables 9 and 10.

TABLE 9

Results of bacterial leaching of coal from mine Dukla

Duration after leaching days	Fe^{2+}, mg/l	S_{total}, %	Amount of bacteria in 1 ml
introduction		1.45	
7	235.10	1.21	$35. 10^8$
14	95.25	0.05	$130. 10^9$
21	75.30	0.95	$160. 10^9$
28		0.90	$135. 10^9$

TABLE 10
Results of bacterial leaching

Sulphur	Before leaching, %	After leaching, %	Level of desulphurization, %
S_{total}	1.45	0.90	37.93
$S_{pyritic}$	0.48	0.11	77.08
$S_{organic}$	0.80	0.70	12.50
$S_{sulphate}$	0.17	0.09	47.06

Character of sample after leaching

The macerals of vitrinite group was after bacterial leaching 70.3%. Most of grains are filled up with secondary minerals with internal reflexion.

There is noticeable influence of leaching after 1 month in the macerals group of liptinite (6.4%).

The macerals of inertinite group were 9% after leaching. The cell walls of fusinite are preserved and cell spaces are filled by secondary minerals.

From the undertermined mineral always prevails pyrite. The framboidal pyrite and euhedral one is bonded to vitrinite. The activity of bacteria can be clearly seen in the Figure 9, where is grain with secondary minerals after pyrite and with partly saved pyrite. In this group of samples pyrite is preserved either entired or partly worked up by bacteria as well pyrite without original high lustre. Smaller amount of the carbonates was identified in this sample.

The changes of coal mass were shown by small pores. The scraps of coal mass were preserved, oxidative margins occured often. Very often large pores were edged by coal mass residues with small pores. The grain of coke character is shown in the Figure 10, in the lower part of figure is inertinite.

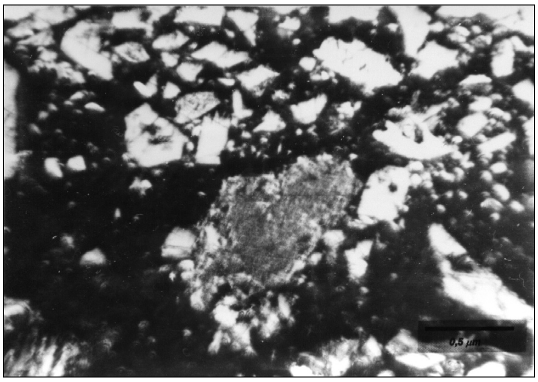

Fig. 9. Filling of secondary minerals after pyrite

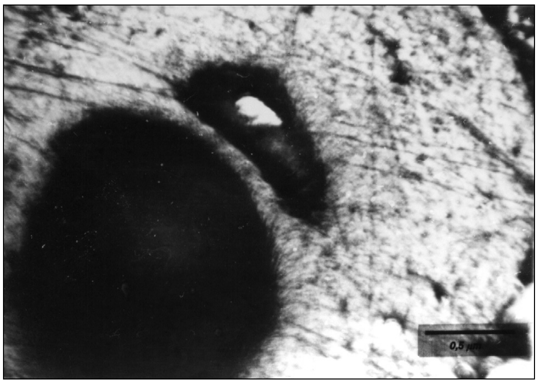

Fig. 10. The grain of coke character

3.6. Character of coal mass after bacterial leaching

This part of the study analyses bacterial leaching results in terms of petrology. During the study a variety of coal samples from different localities in the Czech Republic and Poland have been tested. After detailed petrographical analyses of samples were carried out prior to and post leaching, the results of which are stated in Tables 11 to 14 and Figures 11 to 14, it can be concluded that due to bacterial leaching the content of inorganic foreign matter decreases, extraction of pyrite and its secondary minerals occurs as well as dissolution of carbonates present in the coal, and therefore there is an increase in coal mass in the coal.

TABLE 11
Percentage abundance of vitrinite maceral group in leaching time

Locality	Leching time	(%)
Darkov	before	71.2
	after	73.8
Jankowice	before	77.4
	after	74
Marcel	before	73.8
	after	74
Staszic	before	69.7
	after	70.7
Dukla	before	69.9
	after	70.3

TABLE 12

Percentage abundance of pyrite maceral group in leaching time

Locality	Leching time	(%)
Darkov	before	1.5
	after	0.05
Jankowice	before	2.5
	after	0.6
Marcel	before	1.6
	after	0.4
Staszic	before	1.7
	after	0.2
Dukla	before	1.6
	after	0.1

TABLE 13

Percentage abundance of liptinite maceral group in leaching time

Locality	Leching time	(%)
Darkov	before	5.1
	after	6.9
Jankowice	before	7.4
	after	8.3
Marcel	before	11.1
	after	12.4
Staszic	before	9.6
	after	10
Dukla	before	6.2
	after	6.4

TABLE 14

Percentage abundance of inertinite maceral group in leaching time

Locality	Leching time	(%)
Darkov	before	16.2
	after	17.5
Jankowice	before	4
	after	6.9
Marcel	before	10.2
	after	11
Staszic	before	16.2
	after	18.1
Dukla	before	8
	after	9

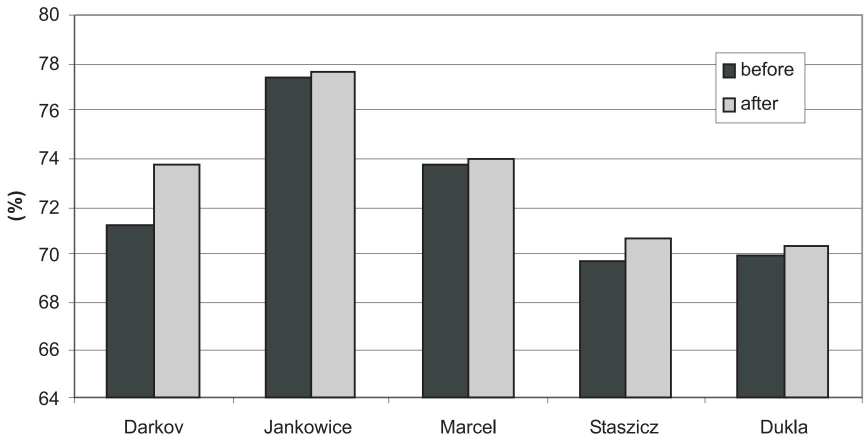

Fig. 11. Percentage abundance of vitrinite maceral group in leaching time

This is clearly documented by this analysis' results where it is apparent that post leaching there is a rise in the content of vitrinite, liptinite, inertinite and the content of pyrite falls. The maceral analysis results further imply that bacterial leaching brings about maceral oxidation and in the samples it is possible to observe spaces filled out by secondary minerals, i.e. spaces from which pyrite was extricated. Bacterial leaching oxidizes individual macerals; vitrinite is at the least resistant to leaching and inertinite is the most.

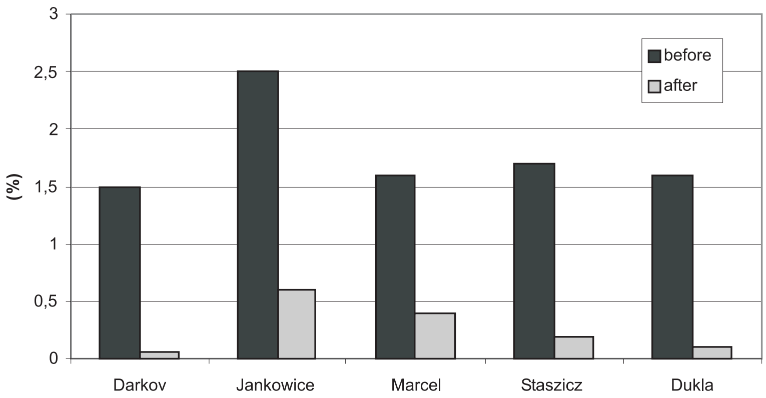

Fig. 12. Percentage abundance of pyrite maceral group in leaching time

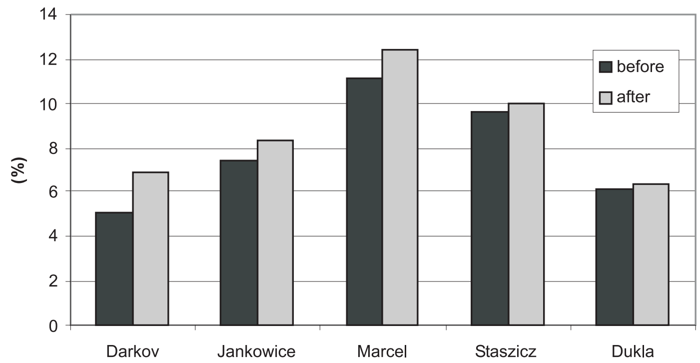

Fig. 13. Percentage abundance of liptinite maceral group in leaching time

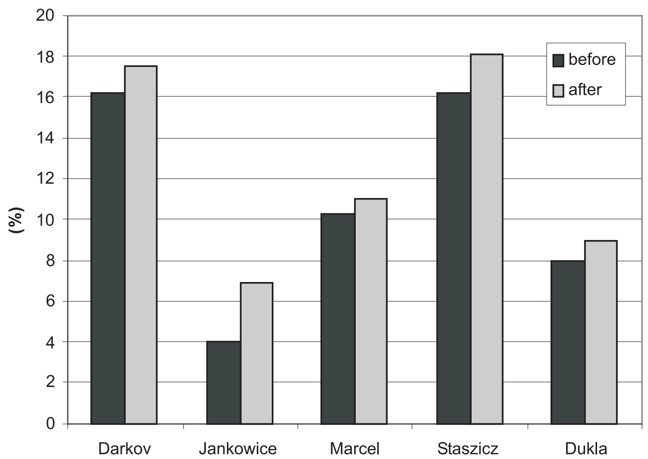

Fig. 14. Percentage abundance of inertinite maceral group in leaching time

4. Conclusion

The aim of the work was the verification of bacterial leaching on the samples of black coals from different localities from Poland (Mine Jankowice, Mine Marcel and Mine Staszic) and from Czech Republic (Mine Darkov and Mine Dukla). From the results obtained it was clear that the coal is very well leached by *Thiobacillus ferrooxidans* and this technology can be used for coal desulphurization. A leaching time of one month is required, to remove from 38% (mine Dukla) to 72% (mine Marcel) of total sulphur and from 60% (mine Marcel) to 82% (mine Staszic) of pyritic sulphur.

From petrographical analyses follows, that with appplication of bacterial leaching growth content of coal mass. Bacterial leaching inductives oxidation of coal macerates and solution of undertermined minerals. It can be said that undertermined mineral was mostly represented by carbonates, less by pyrite, clay minerals and indeterminable mass. Pyrite content decreased with leaching time.

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