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A COMPLEX USE OF THE MATERIALS EXTRACTED FROM AN OPEN-CAST LIGNITE MINE

WIELORAKIE WYKORZYSTANIE MINERAŁÓW WYDOBYWANYCH Z ODKRYWKOWEJ KOPALNI LIGNITU

The company Sokolovská uhelná, was the largest producer of city gas in the Czech Republic. After its substitution by natural gas the gasification technology became the basis of the production of electricity in the combine cycle power plant with total output 400 MW. For the possibility of gasification of liquid by-products forming during the coal gasification a entrained-flow gasifier capable to process also alternative liquid fuels has been in installed. The concentrated waste gas with these sulphur compounds is conducted to the desulphurisation where the highly desired, pure, 96 % H_2SO_4 is produced.

Briquettable brown coal is crushed, milled and dried and then it is passed into briquetting presses where briquettes, used mainly as a fuel in households, are pressed without binder in the punch under the pressure of 175 MPa. Fine brown coal dust (multidust) is commercially used for heat production in pulverized-coal burners. It forms not only during coal drying after separation on electrostatic separators, but it is also acquired by milling of dried coal in a vibratory bar mill.

Slag from boilers of classical power plant, cinder form generators and ashes deposited at the dump are dehydrated and they are used as a quality bedding material during construction of communications in the mines of SUAS. Fly ash is used in building industry for partial substitution of cement in concrete. Flue gases after separation of fly ash are desulphurized by wet limestone method, where the main product is gypsum used, among others, in the building industry.

Expanded clays from overburdens of coal seams, that are raw material for the production of “Liapor” artificial aggregate, are used heavily. This artificial aggregate is characterized by outstanding thermal and acoustic insulating properties.

Keywords: coal, gasification, clean coal technology, combined cycle power plant

Przedsiębiorstwo *Sokolovska uhelna* jest największym producentem gazu miejskiego w Republice Czeskiej. Po jego zastąpieniu przez gaz ziemny, technologia gazyfikacji stała się podstawą do produkcji elektryczności w elektrowni o cyklu mieszanym o całkowitej mocy wyjściowej 400 MW. W celu umożliwienia gazyfikacji ciekłych produktów ubocznych gazyfikacji węgla, zainstalowano na drodze przepływu generator gazu, umożliwiający przetwarzanie alternatywnych paliw ciekłych. Skoncentrowany gaz odlotowy

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zawierający związki siarki odprowadzany jest do instalacji odsiarczającej, gdzie produkowany jest cenny produkt H2SO4, o wysokim stopniu czystości (96%).

Węgiel brunatny nadający się do produkcji brykietów jest kruszony, mielony i suszony, następnie przechodzi przez proces brykietowania w odpowiednich prasach, gdzie formowane są brykiety, poprzez ich sprasowanie pod ciśnieniem 175 MPa. Brykiety takie wykorzystywane są powszechnie jako paliwo w gospodarstwach domowych. Drobnoziarniste pyły węgla brunatnego (paliwa pyłowe) wykorzystywane są na skalę komercyjną do produkcji ciepła w paleniskach pyłowych. Pyły węglowe powstają nie tylko w trakcie suszenia węgla po procesie oddzielania w separatorach elektrostatycznych, lecz także w procesie mielenia suszonego węgla w młynach wibracyjnych.

Żużel z kotłów w konwencjonalnej elektrowni, popioły z generatorów oraz te osadzające się w instalacji podlegają wysuszeniu, następnie wykorzystywane są jako wysokiej jakości materiał na podłoże w różnorodnych instalacjach. Popioły lotne wykorzystywane są przemyśle budowlanym jako częściowe zamienniki cementu. Po oddzieleni popiołu lotnego, gazy wylotowe kierowane są do instalacji odsiarczania z wykorzystaniem technologii wilgotnego wapienia, w wyniku tego procesu powstaje gips, wykorzystywany, miedzy innymi, w przemyśle budowlanym.

Glinki z warstw nadkładu nad pokładami węgla wykorzystywane są powszechnie jako surowiec do produkcji sztucznego kruszywa „Liapor', wykazującego wyjątkowe właściwości termiczne i dźwiękoizolacyjne.

Słowa kluczowe: węgiel, gazyfikacja, czyste technologie węglowe, elektrownia o cyklu mieszanym

1. Introduction

Sokolovská uhelná (SUAS) is a coal-mining and processing company. It comprises two open-cast lignite mines (Jiří and Družba) and owns processing technologies. In the long term, the company engages in the field of the treatment of solid fuels and their energy-chemical conversion into ecologically pure energies. Lignite and to a lesser degree also other minerals from the overburden of lignite layers are mined roughly in the centre of the triangle formed by the largest spa towns in West Bohemia (Karlovy Vary-Mariánské Lázně-Františkovy Lázně). This determines the respect for environmental protection in terms of the influence on both spa thermal springs and the landscape. The large-scale remediation of the effects of mining including agricultural and forestry activities is necessary as well.

The total annual lignite production is currently around 8 mil. t per year. The processing part of the company uses approximately 4 mil. t of the mentioned amount to generate energy. Depending on how much coal needs to be exposed for mining, the amount of the mined overburden is 27-33 mil. m^3 per year.

2. The Antonín Seam and Their Sedimentation Environment

The Sokolov Basin is one of the basins below the Ore Mountains (Krušné Hory). It is most frequently specified as a part of the continental rift. It forms a tectonic, terraced valley filled with extinct volcanoes. It was geologically active in the Tertiary, especially 24-21 million years ago, and lasted approximately 2.7 million years.

The coal basins below the Ore Mountains were a result of the global effect of tectonic forces. Geologically, it is interesting that their developmental stages are roughly coeval with oceanic rifts, and hence also with the folding stages of the Alps and the Carpathians. The tectonic activities in the rift valley coincided with the ideal climate for coal production (the 'Burdigalian Optimum'). The geometry of the faults of the Sokolov Basin indicates the Tertiary expansion of deeper plastic horizons of the Earth below the valley floor, which then forced the brittle Earth's crust to break. The locking of tectonic bocks created space for the sedimentation of clays, bogs and peats – the future coal seams. A major consequence of the existence of deep-reaching cracks was volcanism. Volcanic products, now masked by transformations lasting millions of years, form more than 50% of the volume of the filling of the Sokolov Basin. Some of them have been used as valuable materials. The main coal seam Antonín was deposited approximately 22 million years ago. The stratigraphy of the Sokolov series of strata including Antonín strata and the geochemistry of the sediments of the Sokolov Basin have been described in detail in (Rojík, 2004, 2006; Křibek et al., 1998).

Coal mining is now concentrated in the central part of the Sokolov Basin. The Antonín seam is up to 40 metres thick in the Jiří mine field and 35 metres thick in the Družba mine field. The coal faces of both mines run towards the west, where they meet the caved goafs created by underground mining activities mostly in the 19th and 20th centuries. As the amount of the mined coal gradually increases, there are growing demands on the selective mining of coal mass and on the removal of undesirable admixtures – the remains of underground mining, including wood-mass residues.

3. Coal Petrography, Composition and Properties

Old mines have significantly disrupted the coal seam, which means that they considerably have changed the quality of the coal mined. These changes are caused by the effect of air oxygen and the admixture of the sunken overburden.

Micropetrographically, the coal typical of the Antonín seam is a hard lignite, specifically a lignite metatype (based on the reflectance of the light form of ulminite B – see Table 1). A dominant maceral group is huminite, in particular its gelified macerals densinite and ulminite. The effect of air on the coal in the mined parts has been manifested only by a slight decrease in the reflectance; otherwise, it is not much reflected in the petrography (Sýkorová, 2003).

TABLE 1

A micropetrographic analysis of lignite from the Antonín seam roof

Genesis	R_r (%)	HUMINIT									
		Σ	Att	Dens	Tex	Ulm	Gel	Korp			
Roof	0.36	70.8	0.5	24.7	3.0	37.0	2.6	3.0			
Roof < 0.2 mm	0.36	70.0	0.9	30.3	1.7	34.7	0.8	1.6			
		LIPTINITE									
		Σ	Spor	Alg	Cut	Flor	Sub	Res	Exs	Liptd	Bit
Roof	0.36	11.9	2.6	0.7	1.2	0.8	0.3	3.0	0.0	2.2	1.1
Roof < 0.2 mm	0.36	8.2	1.2	0.4	0.8	0.2	0.0	2.0	0.0	2.8	0.8
		INERTINITE						MINERALSUBSTANCES			
		Σ	Fus	Scle	Makr+Smf		Id				
Roof	0.36	2.6	1.0	1.1	0.5		0.0	14.6			
Roof < 0.2 mm	0.36	2.8	0.8	1.3	0.0		0.7	19.0			

Note: R_r – light reflectance, Σ – the amount of huminite, liptinite, inertinite, Att – attrinite, Dens – densinite, Tex – textinite, Ulm – ulminite, Gel – gelinite, Corp – corpohuminite, Spor – sporinite, Alg – alginite, Cut – cutinite, Flor – florinite, Sub – suberinite, Res – resinite, Exs – exsudatinite, Liptd – liptodetrinite, Bit – bituminite, Fus – fusinite, Scle – sclerotinite = funginite, Macr – macrinite, Smf – semifusinite, Id – inertodetrinite

Important technological properties of the coal mass from both mines are shown in Tables 2 and 3 (Smolík et al., 2000; Sýkorová et al., 1999b).

TABLE 2

The average parameters of the Antonín seam coal

Parameter/sample	Jiří	Družba
W^r (moisture content, %)	31.24	30.40
A^d (%)	18.59	17.52
A^r (%)	12.79	–
S^d (all) (%)	1.00	0.96
S (pyritic) (%)	0.24	–
S (sulphate) (%)	0.73	–
Q_i^r (heating value, $MJ.kg^{-1}$)	15.66	16.11
C^r	42.82	38.90
Volatile combustible (%)	51.50	51.30
Q_s^{daf}	30.64	–
C^{daf} (%)	73.00	–
H^{daf} (%)	5.89	–
S^{daf} (organic) (%)	0.61	–
N^{daf} (%)	1.06	–
O^{daf} (%)	19.44	–

TABLE 3

The combustible and the basic petrography of the coal mass

Parameters	Jílovec (cypress c.)	DX-Ant	LD-Ant	High-ash-content Ant. coal
A^d (%)	78.9	7.2	10.2	33.32
S_t^d (%)	0.2	0.6	1.0	1.12
Q_s^{daf} ($MJ.kg^{-1}$)	-	30.7	34.7	30.25
C^{daf} (%)	7.2*	73.1	76.7	70.27
H^{daf} (%)	1.6*	5.6	8.3	6.04
R_r (%)	0.33	0.41	0.38	–
Huminite (vol.%)	3.0	85.5	65.3	–
Liptinite (vol.%)	93.7	13.1	28.3	–
Inertinite (%)	3.3	1.4	6.4	–

*) C^d a H^d, cypress-c. = cypress clay sediment, DX-Ant = detroxylitic coal from the Antonín seam LD-Ant = liptodetritic coal from the Antonín seam; several parameters of the high-ash-content coal (DX) from the Antonín seam are listed for comparison.

Although previous mining has a minimum impact on coal petrography, old mines clearly affect coal reactivity. During laboratory measurements, pillar-coal gasification reactivity (carboxi-reactivity) reached ca 1.5 %/min; it was thus roughly 15% higher than that of the roof (caving) coal. The difference was discernible both in the gasification of the pyrolysis product acquired from coal samples and directly in coal gasification (Sýkorová et al., 1999a).

To complete the illustration of the characteristics of the coal processed, its reactivity should be compared with the reactivity of lignite from other deposits. Samples of the Jiří Mine coal studied were tested in Mulgrave (HRL, Australia) in an experimental fluidised-bed gasification generator. During the test, the profiles of the mass loss caused by the reaction of the carbon contained in a sample with CO_2 (according to the reaction $C_{(s)} + CO_{2(g)} => 2\ CO_{(g)}$) under a pressure of 1 MPa were continuously recorded.

In the same extent of carbon conversion and with similar parameters affecting reaction kinetics (under a CO_2 pressure of 1 MPa and at a temperature of 563°C), the average reactivity of the mined-seam coal sample was much lower than that of the coal from a grown seam – only 0.57 %/min., which is on the level of a mere one-third of the reactivity of the grown-seam coal sample. Under comparable reaction conditions, the typical gasification reactivity of the Australian coal mined in the Victorian Latrobe Valley is approximately 3-5 %/min. The reactivity of the German coal mined in the Rhine Basin is even slightly higher (Mika, 2005).

Even without the influence of previous mining activities, the Sokolov lignite has a lower carboxireactivity than Australian and German coal.

4. The Use of Coal in Actual Plants

4.1. Briquette Production

Having been crushed, ground to a grain size below 6 mm and dried, briquettable lignite from selected parts of the Antonín seam was transported to briquetting presses PZA 300, in which briquettes were pressed without any binding agents in stamping presses under a pressure of 175 MPa. The parameters of the briquettes made are shown in Table 4.

TABLE 4

The parameters of the briquettes made

Parameters	Unit	Value
Water content	wt. %	10-12
Ash content	wt. %	max. 15
Briquette abrasion resistance	%	min. 84
Briquette compressive strength	MPa	min. 5.6
Briquette width	mm	182
Sulphur content (S^d)	wt. %	max. 0.6
Heating value Q_i^r	MJ/kg	22.2-22.6

The briquetting of lignites without binders is a multifactorial issue. It depends on the physical and chemical properties of the processed coal, in particular the content of capillary water and ash, hardness, plasticity, grain size and petrographic composition (mainly the share of huminite). The amount of briquettable coal, however, has dropped so much that briquette production was discontinued in 2010.

4.2. Syngas and Electricity Production in a Combined Cycle

Coal reactivity has prepared uneasy prospects for gasification processes, which are the basic pillar of the main direction of processing technologies – electricity generation in a combined cycle power plant (CCPP). The combination of these technologies resulted in a new coal-processing procedure and the use of its energy content close to the trend generally called 'clean coal technology' (CCT).

The actual syngas production process (high-pressure gasification of lignite by an oxygen–steam mixture under a pressure of 2.7 MPa in generators with a solid bed and a fixed bed, raw-gas purification by a modified methanol scrubbing method using the Rectisol system, preserving a significant amount of CO_2 in the syngas) and its application in a combined-cycle power plant (two FRAME 9 E gas turbines with a capacity of 309 MW_e, 2 steam turbines PP 60-71 with a capacity of 114 MW_e, an annual supply of 2,750 MWh) were described in (Blatchford & Johnson, 2002; Bučko et al., 1996, 2005; Buryan et al., 2005).

A great advantage of this system is the short time (several minutes) between the start and the connection to the distribution network. A major plus of this solution is also the possibility of using natural gas during the start of the steam-gas generator, which is fed to the system under the necessary pressure.

4.3. Heat Production in a Conventional Power Plant

High-pressure steam of 13.5 MPa and 540°C is produced by burning pulverized coal with a grain size of < 5 mm in boilers with powder burners with a nominal capacity of 325 t/h. The steam is used to generate electricity in turbogenerators with a capacity of 55 MW. A part of the steam – extracted from turbines of pressures of 3.5 and 0.5 MPa – is used to dry and gasify coal and is the source of heat not only in many plants but also in the heat distribution system for the housing estates in the vicinity of the plant, including the spa town of Karlovy Vary (Carlsbad).

5. Coal Utilisation By-Products

5.1. From Coal Treatment

Coal charges for conventional power plants and for gas-producer plants undergo the treatment processes of crushing and drying.

The slack released through the improperly sealed parts of the technology in the crushing plant is rinsed with water into a separate sewer. The other coal-treatment plants are rinsed similarly.

In the drying plant, mined (raw) coal was dried from the initial 38-46 wt. % to 12-18% for a conventional power plant and to 28-32% for a gas-producer plant. The drying process took place in steam-pipe dryers of the Schulze type. Steam-laden emissions coming out of the dryers were fed into electrofilters, where entrained coal-dust particles were separated. The coal for the briquetting plant was dried in a similar device, only the degree of drying was higher (to 7-12%). Also here, electrofilters were installed to separate coal dust. The coal dust from the electrofilters was fed by bulk conveyers to a multi-dust collector. The fine lignite dust (multi-dust) produced is commercially used to generate heat in powder burners (Kijo-Kleczkowska, 2013); nevertheless, it is produced not only when coal is being dried after it was captured on electrostatic separators, but it is also acquired by grinding dried, originally briquetting coal in vibration rod mills of the Palla type with the target production volume of 300 000 t/year. The multi-dust characteristics are shown in Table 5.

The dust is removed from the whole equipment (belt conveyers, bulk conveyers, briquetting presses) by exhausting the air mass with coal dust by means of ventilators, feeding them into water scrubbers. The captured dust is then combined with the dust rinsed from the devices in a slack-water purification plant.

Having been purified, waste water from the crushing, drying and briquetting plants is recirculated. Once the gross slack sludge from the purification has been drained, it is used to produce energy; after flocculation, the fine sludge from the chemical phase of the purification plant is deposited and may be used in agriculture.

TABLE 5

The parameters of lignite multi-dust

Parameters	**Unit**	**Value**
Medium grain size	mm	0.045
Ignition point (settled dust)	°C	270
Incandescence point – settled dust	°C	345 (τ_i = 1 s)
Flammability point – raised dust	°C	428
Bulk density	kg/m^3	560
Water content	wt. %	4.5–7.0
Ash content	wt. %	15.5–18.0
Coal-mass content	wt. %	73–79
Of which volatile combustible	wt. %	39.6–40.2
Heating value Q_i^r	MJ/kg	20–25

5.2. From a Conventional Power Plant

Having come out of the dryers, the coal (green underflow from conveyers) is burnt in boilers with powder burners. Slag from the coal combustion in the boilers is transported by a stream of water into crushers and carried in a water mixture to an ash sanitary landfill. Fly ash from boiler draught and from the mechanical separator of flue-gas ash is added to its flow. Boiler and generator slag as well as fly ashes deposited at landfills are extracted by excavators, are drained and used as a quality sub-base material in the construction of internal roads in quarries.

Fly ash from electrostatic separators (before the input for flue-gas desulphurisation), whose typical composition is listed in Table 6, is utilised in the construction industry to replace a part of cement in concrete. Most particles have a diameter of 2-4 mm. From the annual production of ca 150,000 t of fly ash, the construction industry uses ca 60,000 t; having been mixed with a part of the mined overlying rock, the rest is utilised to reinforce internal dumps in quarries.

TABLE 6

The composition of power-plant fly ash

Parameters	Unit	Value
Grain < 0.004 mm	vol. %	82.5
Unburnt residue	wt. %	< 1.0
Amount: SiO_2	wt. %	39-45
Al_2O_3	wt. %	28-35
Fe_2O_3	wt. %	5-12
CaO	wt. %	2-10
MgO	wt. %	0.3-0.6
SO_3	wt. %	0.4-1.3

After fly ash is separated, flue gases are desulphurised using the wet limestone method. In an absorber, untreated flue gases come into contact with a recirculation suspension containing lime. Chemical reactions take place here, ensuring the removal of SO_2, HCl and HF, and to a certain degree also of SO_3 from flue gases. The main product is gypsum, $CaSO_4.2H_2O$. From the annual production of ca 60,000 t, one-third is used for the plants' own use; the rest is utilised in the construction industry.

5.3. From a Gas-Producer Plant

Heavy tar sludge separated by gravity in the processes of gas-condensate separation and crude-phenol-water purification is sprayed back into the generators for gasification.

Generator ash discharges are de-ashed using a damp method; a water mixture is flown onto an ash landfill. The use of the ashes deposited is mentioned in Chap. 5.2.

5.4. From Crude-Phenol-Water and Raw-Generator-Gas Purification

The generator gas leaving the generator, or precooler, has a temperature of ca 200°C. It goes through a cooling system and enters Rectisol with the maximum temperature of 30°C. When it is being cooled, both water vapours and the vapours of a rich mixture of organic substances are condensed. The condensate is conducted to unpressurised separation, where tar is separated from the water phase (phenol water) by gravity and where heavy tar sludge is sedimented. The tar is further modified in tanks by dewatering into the dispatched product called lignite generator tar.

In the next device, the phenol water is extracted by butyl acetate (*phenolsolvane* process). The resulting product is a phenol concentrate containing mainly monobasic and dibasic phenols. In stripping columns, dephenolised water is stripped of ammonia and then led to the final biological purification.

The raw gas entering Rectisol is first rinsed with a mixture of water and petroleum hydrocarbons in the cooling circuit, which removes crude petrol, ammonia and HCN from it. Subsequently, the gas passes through a methanol scrubbing solution, during which especially hydrogen sulphide, but also COS and reduced thiols are separated from it. The concentrated waste gas with these sulphur compounds is conducted to the WSA desulphurisation unit WSA, where the highly desired, pure, 96 % H_2SO_4 is produced.

The liquid by-products of pressure gasification are thus lignite generator tar, phenol concentrate, liquid ammonia, sulphuric acid and Rectisol petrol. Tar is used as a fuel for heating plants and as a fuel with reduction properties in blast furnaces in raw-iron production. The phenol concentrate, liquid ammonia and H_2SO_4 are supplied for further chemical treatment.

Crude petroleum is utilised for the thermal stabilisation of the operation of the unit for the disposal of expansion (and penetrant) gases from Rectisol and for the production of syngas in an entrained flow reactor.

The overview of the substances listed above must be complemented by organic substances separated during the ammonia elimination process; these are the substances that are driven off from the dephenolised water in stripping columns as residual along with ammonia and are separated in the liquid ammonia refining process. Their dominant components are oxygen and nitrogen compounds. Subsequently, they are mixed with Rectisol petroleum and gasified.

The characteristics and the basic qualitative parameters of the mentioned products were published in (Bučko et al., 2005; Buryan et al., 1982, 2005; Mika, 2005, 2006; Buryan & Kuraš, 1982).

6. The Mining, Properties and Use of the Materials Extracted in Coal Excavation

The lignite overburden contains some non-traditional raw materials that represent interesting potential for commercial use. Many rocks occurring in the overburden of coal seams used to be unknown, underestimated and used to lie at dumps in the long term without any use. Thanks to new insights, they have become subject of research and exploitation

Nowadays, they are valuable raw materials for the reclamation and revitalisation of the Sokolov landscape and save a substantial amount of money that would otherwise have to be exerted on the import of raw materials from other areas. In addition, they enrich the raw-material market with cheap materials for the production of construction and ceramic materials, they find application in environmental-protection projects and in the resolution of the technological problems that occur in the substitution of expensive and unavailable materials (Pomykal, 2013).

The formation and properties of coal seams have been significantly affected by volcanism and tectonics (as already mentioned in Chap. 2) – positively by the creation of sedimentation depressions and negatively by the local reduction of former peat bogs by pyroclastic rocks, the splitting of seam and contamination by ash. What is very interesting is titan mineralisation, whose source was basic volcanism. TiO_2 content in rocks is lower in the regional kaolin background (1.1 wt. %), higher in basalts (2-5 wt. %) and kaolinised tuffs (5-11 wt. %), and the highest in kaolinised coaly epiclastic rocks (7-16 wt. % of TiO_2) (Sýkorová, 2003). These clay-like rocks are used as yellow-pigment components of ceramic materials.

In the past, the Antonín strata yielded not only coal but also siderite nodules for blast-furnace charges. The siderite nodules were formed above the volcanic ridges in the seam floor. The nodules are located in grey-brown kaolinitic claystones with coal, tuff, clastic and cementing admixtures. There are two types of the coal admixtures: 1) autochthonous, dispersed liptodetrite-type grains, 2) allochthonous fusite and oxidised-xylite fragments, brought by water. During diagenesis, abundant siderite nodules formed around the fusite fragments, which represented the reduction microenvironment (Rojík, 2004).

In 1960-1964, a survey of germanium content in the Antonín coal was conducted at the Silvestr, Lomnice and Michal sites. Despite the results being positive, $GeCl_4$ production has not been introduced; on the other hand, the ash from the Josef seam at the Lipnice site has found application (Lachema Kaznějov).

Nevertheless, the expanded clays of the cypress strata in the Antonín seam overburden have been widely used. Since 1964 already, these clays have been a raw material for the production of the synthetic aggregate Liapor (expanded clay) (Maršák & Buryan, 2002, 2003; Buryan & Maršák, 2010). In terms of composition, these are illite-kaolinite clays with an admixture of minerals facilitating melting and expansion (siderite, dolomite, calcite). When fired at a temperature above 1100°C, the clays expand and create ceramic granules with a porous structure and a sintered surface. The granules are used for the production of lightweight aggregates with excellent heat and sound insulation properties, lightweight concrete, building components, blocks, tiles, garden architecture etc.

Polymineral clays with adsorbent properties are capable of absorbing heavy-metal ions, crude-oil substances and polychlorinated biphenyls. The active ingredients of these clays are montmorillonite, illite, organic matter of algal origin and carbonates. The clays are utilisable as earth-filter media, sorption layers at landfills, barriers with combined sorption and sealing effects, for substrate and garden-soil production and in particular for land reclamation. It is interesting that the deposited clay substrate lowers the acidity of the water at landfills (Hezina, 2000).

Thanks to their grain structure and mineralogical composition, sealing soils are able permanently to retain water and aqueous extracts. They are used for the mineral sealing of landfills and contaminated sites, for the sealing of water reservoirs and for land reclamation. Especially now, the landscape around Sokolov, damaged by surface coal mining, is being reclaimed by the creation of water reservoirs, in which these overburden soils are utilised quite successfully.

Analcime clay is a non-traditional raw material, a 'Sokolov specialty', which has been formed by the reaction of volcanic ash and salt lake water. It may be used as a filling agent, in the production of garden substrates and soils, for soil improvement, for the cleaning and filtration of contaminated environments etc. The main useful components of the claystone are analcime (a zeolite group mineral), montmorillonite, illite, feldspars and carbonates.

Other interesting raw materials uncovered in coal mining are decorative stones, mineral pigments, ceramic clays, oxyhumolites and sapropelites.

7. Conclusion

The above-described principles of applied technological procedures of clean-energy production have significantly improved coal utilisation. It has been demonstrated that the quality of the coal that is being mined now is affected by the previous mining activities. For conventional electricity and heat-distribution technologies, where coal is burnt in powder burners, the deteriorating fuel quality (caused chiefly by the rising ash content) is bearable especially with respect to the composition of the ash matter influencing the ash melting point (around 1400-1500°C, which is the range in which boilers are not clogged with slag).

In the case of fixed-bed generators, however, the growing ash content and oxidised share of coal increases the number of the cleaning cycles necessary (it raises their shutdown frequency). There is also a higher risk of the creation of the emulsions of liquid products that are hard to treat, and gas yield decreases in connection with the lower coal gas capacity and coal gasification reactivity. In Vřesová, these tendencies have been balanced by the newly implemented entrained-flow technology, gasifying the liquid products of conventional coal gasification.

Appropriate investments and technological modifications have made it possible both to give the original technology the form of a modern processing complex and to use the deposits with mined seams and caved goafs effectively not only for the production of environmentally clean energies within the actual lignite treatment, but also for the complex use of the hidden overlying rocks in the creation of new landscape features and in industrial clay processing.

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