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Valorization of coal mining waste dumps from the mines of Jastrzębska Spółka Węglowa SA for the needs of recovery of coal and further reclamation and management

Introduction

The processes of coal exploitation (independent of the applied technology) as well as coal preparation are accompanied by the origination of waste rock. The mining of 1 Mg of hard coal is connected with the excavating of ca. 0.4 Mg of waste rock (Gawor et al. 2015). Mining wastes are disposed on the surface and underground dumping grounds, in flotation tailings and a part of the material is re-used e.g. in underground mining technologies, for the purposes of ground levelling and in engineering and hydrotechnical construction works. Waste rocks come from Carboniferous lithostratigraphic series (extracted during preparatory works or exploitation of coal seams) as well as from the overburden of Carboniferous rocks (mined during excavating of shafts).

They can be divided into mining wastes and preparation wastes. In 2014, mining exploitation was accompanied by the origination of 71.8 million Mg of coal mining wastes corresponds to ca. 55% of the amount of industrial wastes in Poland (Probiez et al. 2017).

Coal mining dumping grounds have a negative impact on the environment. The main hazards include: self-ignition and fire dangers as well as the contamination of surface and underground waters.

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Over 226 coal mining waste dumps are situated in the region of the Upper Silesian Coal Basin (USCB). They are usually located around coal mines and central dumps, situated on the peripheries of the USCB, where the wastes have been stored by different mines (e.g. Smolnica, Przezchlebie or Maczki-Bór). Waste dumps after hard coal mining in the Polish part of the USCB cover more than $4000 \cdot 10^4 \text{ m}^2$, and the volume of the gathered wastes is estimated on ca. 700 million Mg (Sikorska-Maykowska 2001; Gawor 2014).

There is a need to carry out the efficient reclamation of both technical and biological the dumps and the simultaneous carrying out of recovery processes as well as the future use of the degraded areas.

The main reason for conducting the research, the purpose of which is inventORIZATION, mapping and valorization of hard coal mining dumps of the mines from Jastrzębska Spółka Węglowa SA was a lack of actual and uniform data (divergent information concerning e.g. surface of the dumps appears in the literature), as well as the dynamic nature of the changes of these facilities where the waste material is still disposed.

The described facilities represent different types and have been reclaimed and managed in different ways and directions. The author's methodology (Probierz et al. 2017) concerning reclamation and potential coal recovery was applied in the process of valorization of the dumping grounds.

1. Localization and characteristics of the study area

The study area encompasses mining areas of four hard coal mines of Jastrzębska Spółka Węglowa SA (JSW company): the Borynia-Zofiówka-Jastrzębie coal mine, the Budryk coal mine, the Knurów-Szczygłowiec coal mine and the Pniówek coal mine and mining areas of two mines presently belonging to Spółka Restrukturyzacji Kopalń SA (Mines Restructuring Company): the Jas-Mos coal mine and the Krupiński coal mine (Fig. 1).

JSW SA, founded April 1, 1993, is the largest producer of coking coal and the basis of its activity is the production and sale of coking coal and energetic coal. The coal mined by the mines of JSW SA, mainly coking coal, is used as coke by metallurgic plants and other enterprises (Table 1).

The JSW SA mines together possess ca. 6.2 billion Mg of coal resources. JSW SA plans to extend the base of operative resources, which enables the strong position to be maintained on international markets for the next dozens of years. In 2016, the JSW SA mines produced 16.8 million Mg of coal, including 11.6 million Mg of coking coal and 5.2 million Mg of energetic coal (www.jsw.pl).

In the lithostratigraphic profile of the study area, Carboniferous productive series (Fig. 2) and overburden rocks occur in spite of basement rocks.

There are three Upper Carboniferous lithostratigraphic series in the deposit series: Paralic, Upper-Silesian Sandstone and Mudstone Series. The Paralic Series (Serpukhovian) is represented by Pietrzkowickie layers (seams with 900 numbering), Gruszowskie layers (seams

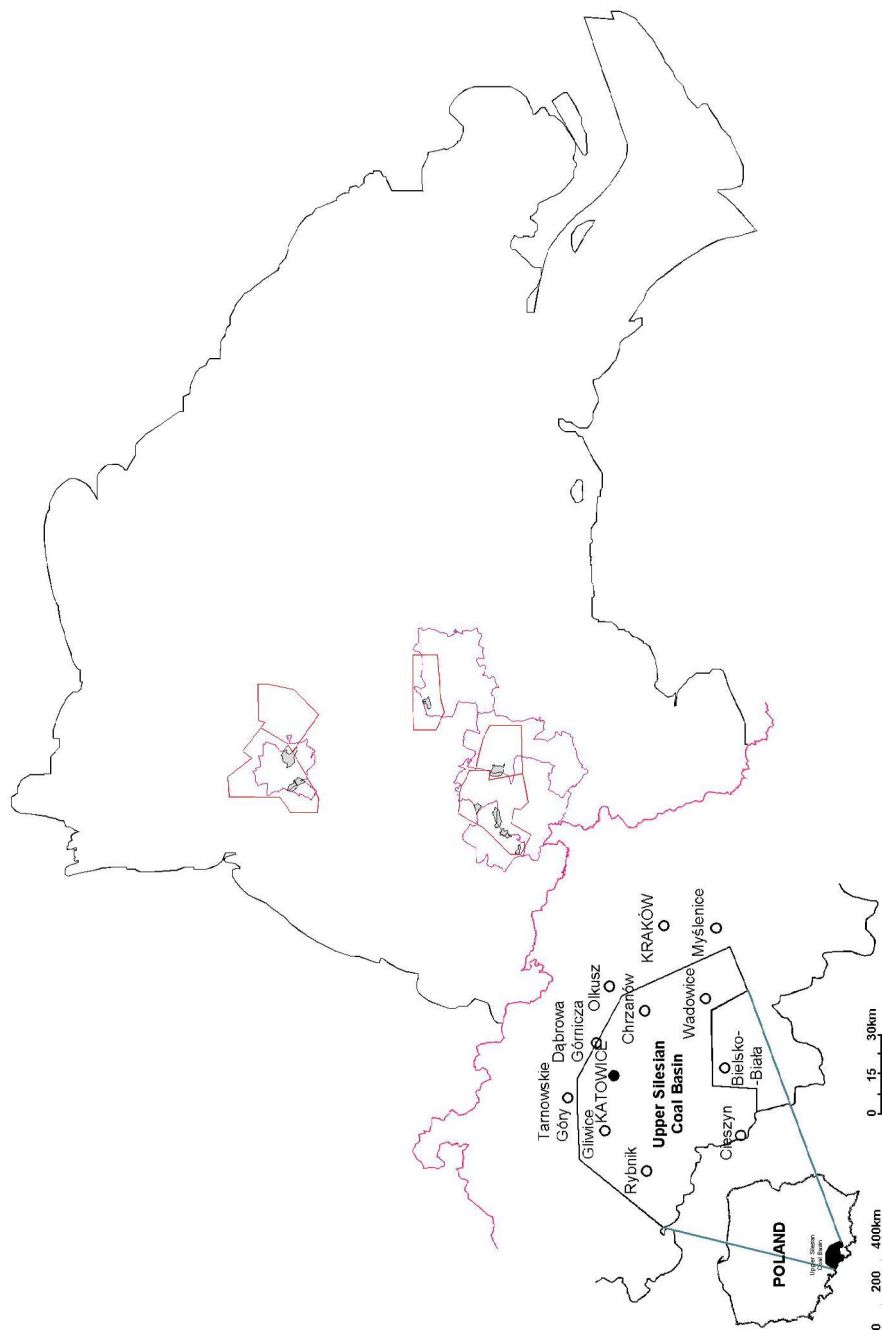


Fig. 1. Sketch of the location of study area

Rys. 1. Szkic lokalizacji obszaru badań

Table 1. General characteristic of hard coal deposits (www.jsw.pl)

Tabela 1. Ogólna charakterystyka złóż węgla kamiennego

No.	Deposit	Surface (km ²)	Operative resources (mln Mg)	Coal type according to PN-82/G-97002	Thickness of seams (m)	Inclination of seams (°)	Natural hazards methan, cat. water, degree. seismic, degree. dust, class.
1.	Borynia	17.4	31.9	35.1, 35.2A, 35.2B	1.6–4.0	2–16	III I and II I A and B
2.	Jastrzębie	35.2	18.8	35.2B, 37.1	1.3–5.5	6–28	IV I, II and III I and II A and B
3.	Zofiówka	16.4	61.1	35.1	1.1–4.0	2–18	IV I and II I and III A and B
	Bzie-Dębina 2-Zachód	10.4	36.6				
4.	Budryk		223.5	34.2	1.6–2.3	4–6	IV I and II I A and B
	Ornontowice 1	36.0					
	Ornontowice 2	4.6					
5.	Knurów	38.5	154.1	34.2	1.6–3.1	6–26	I–IV I and II I B
6.	Szczygłowice	21.3	180.3				
7.	Pniówek	28.6	101.9	35.1	1.4–2.4	3–14	IV I and II I A and B
	Pawłowice 1	15.8	54.0				
Total:		224.2	862.2	34.2–37.1	1.1–5.5	2–28	I–IV I–III I–III A and B

with 800 numbering), Jaklowieckie layers (seams with 700 numbering) and Porębskie layers (seams with 600 numbering). Upper-Silesian Sandstone Series are represented by Saddle layers (seams with 500 numbering, Serpukhovian) and Rudzkie layers (seams with 400 numbering, serpukhovian). Mudstone Series are represented by Załęskie layers (seams with 400 and 300 numbering, Bashkirian) and Orzeskie layers (seams with 300 numbering, Bashkirian).

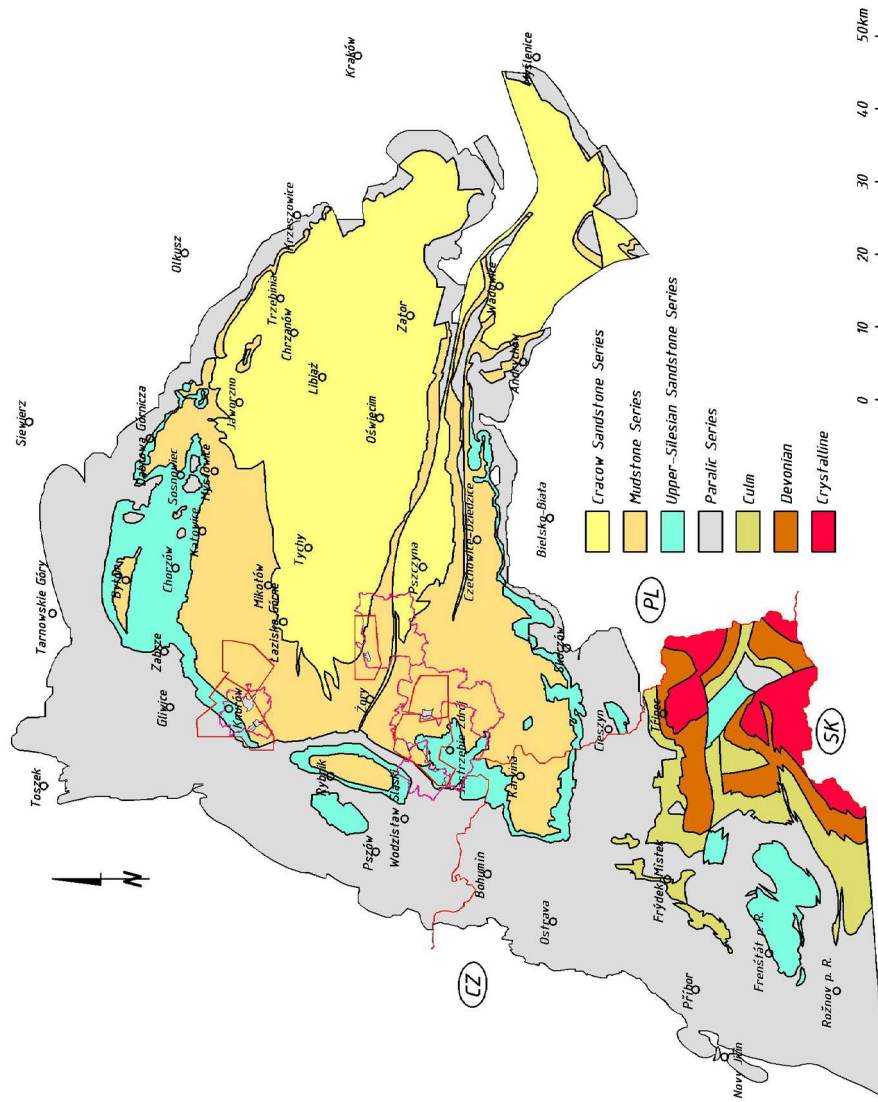


Fig. 2. Location of the study area against the background of the geological composition of the USCB

Rys. 2. Lokalizacja obszaru badań na tle budowy geologicznej GZW

The overburden is represented by Triassic rocks (occurring in a form of isolated patches lying directly on the roof of Carboniferous strata of the deposit Szczygłowice) and Miocene and Quaternary rocks, characterized by a differentiated lithological formation and different thickness (Gabzdyl 1966; Probierz et al. 2012).

Important tectonic disturbances, often with regional significance, occur within the boundary of the study area and the boundaries of analyzed mining areas of the mines and deposits (Fig. 3). The most important are: Orłowa-Boguszowice overthrust, called *nasunięcie orłowskie*, the Knurów-Leszczyny fold (*fald knurowsko-leszczyński*), transiting into the Sośnica-Knurów fold (*fald Sośnicy-Knurowa*), the Jastrzębie fold (*fald Jastrzębia*), the Gorzyce-Bzie Zameckie-Czechowice-Kęty fault zone, faults: Jastrzębie, Pniówek, Pochwacie, Krzyżowice I and II, Pawłowice I and II as well as Warszowice (Probierz et al. 2012).

The deposits characterized by the high diversity of the formation, thickness and quality of the seams, complicated tectonics, numerous faults creating zone of tectonic disturbances which makes running continuous and safe exploitation impossible, numerous interlayers of waste rocks, variability of quality parameters of coal enabled to qualify them to the second group of the variability of deposits (Probierz et al. 2012).

Natural hazards include: methane hazards (I–IV categories), water (I–III grade), burst (I–III grade) and explosion of coal dust (class A and B, Table 1).

2. Source data and methodology

The source material for this research comprise statistical data with the localization of particular dumps obtained from archival materials from coal mines and municipalities where the dumps occur (Jastrzębie Zdrój, Knurów, Mszana, Pawłowice, Suszec).

An inventorization of 10 coal mining waste dumps coming from four coal mines of Jastrzębska Spółka Węglowa SA and two mines belonging at the moment to Spółka Restrukturyzacji Kopalń SA was carried out on the basis of the analysis and verification of accessible data. The research works encompassed 9 deposits: Borynia, Jastrzębie, Moszczenica, Zofiówka (with the Bzie-Dębina 2-Zachód deposit), Budryk (with Ornontowice 1 and Ornontowice 2 deposits), Knurów, Szczygłowice, Pniówek (with Pawłowice 1 deposit) and Krupiński.

The localization of particular waste dumps was verified in the first stage on the basis of topographical maps, orthophotomaps and actual aerial photographs and during field works in the second stage. The result of this stage of the research is a map of coal mining waste dumps (Fig. 4).

The next stage of the research included individual works meaning the valorization of the dumps using description mode, containing the definition of: name of the dump, name of the coal mine from where the wastes come from, state of the dump, surface of the dump, type of technical and biological reclamation, accessibility of the facility and possibilities of coal recovery. The results of the valorization have been shown on the drawn map (Fig. 4).

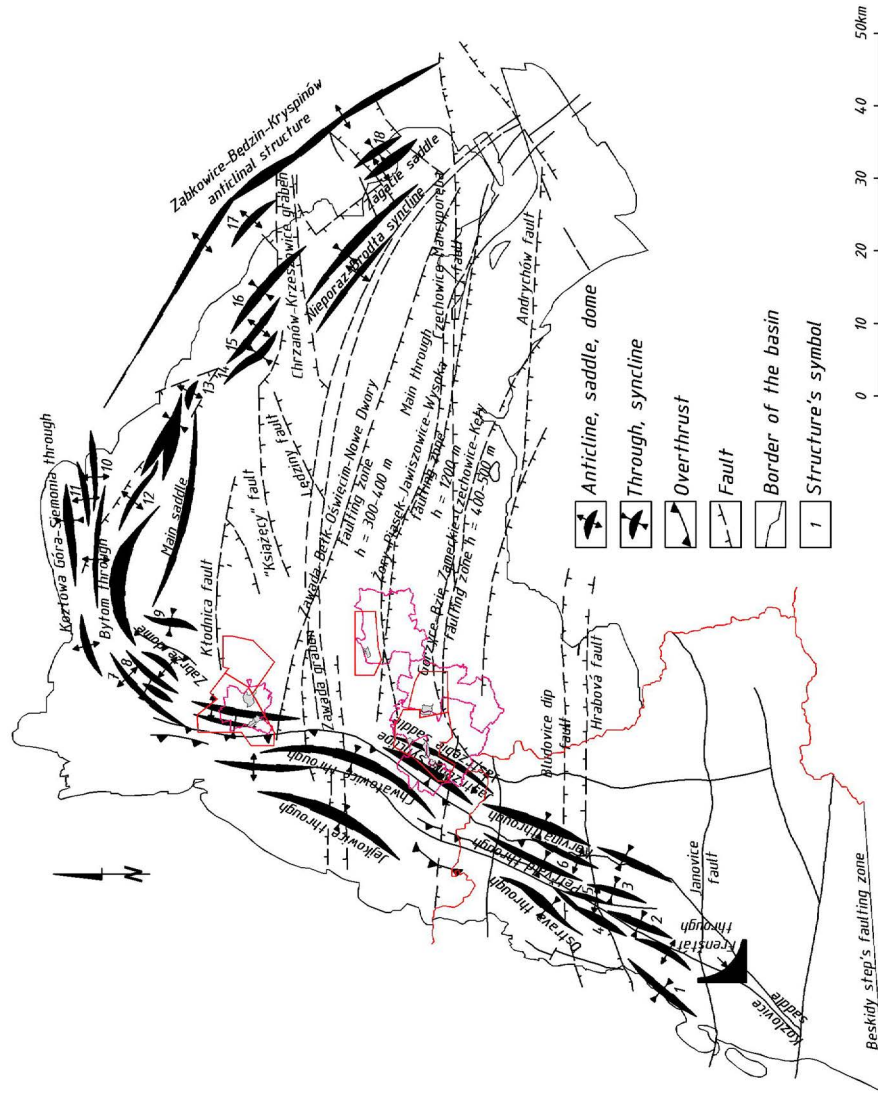


Fig. 3. Location of the study against the background of the main geological structures of the USCBS

Rys. 3. Lokalizacja obszaru badań na tle głównych struktur geologicznych GZWS

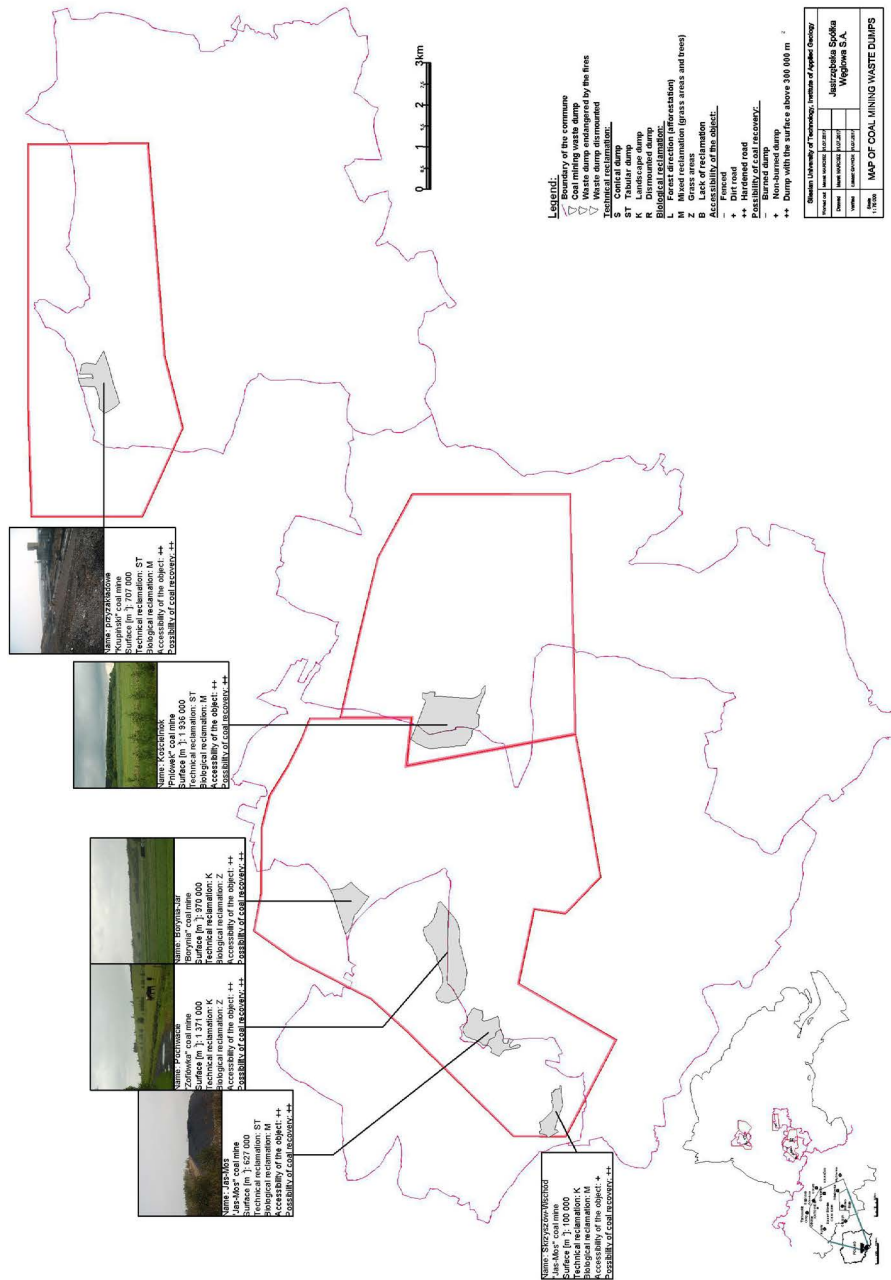


Fig. 4A. Map of coal mining waste dumps

Rys. 4A. Mapa zwałowisk po górnictwie węgla kamiennego

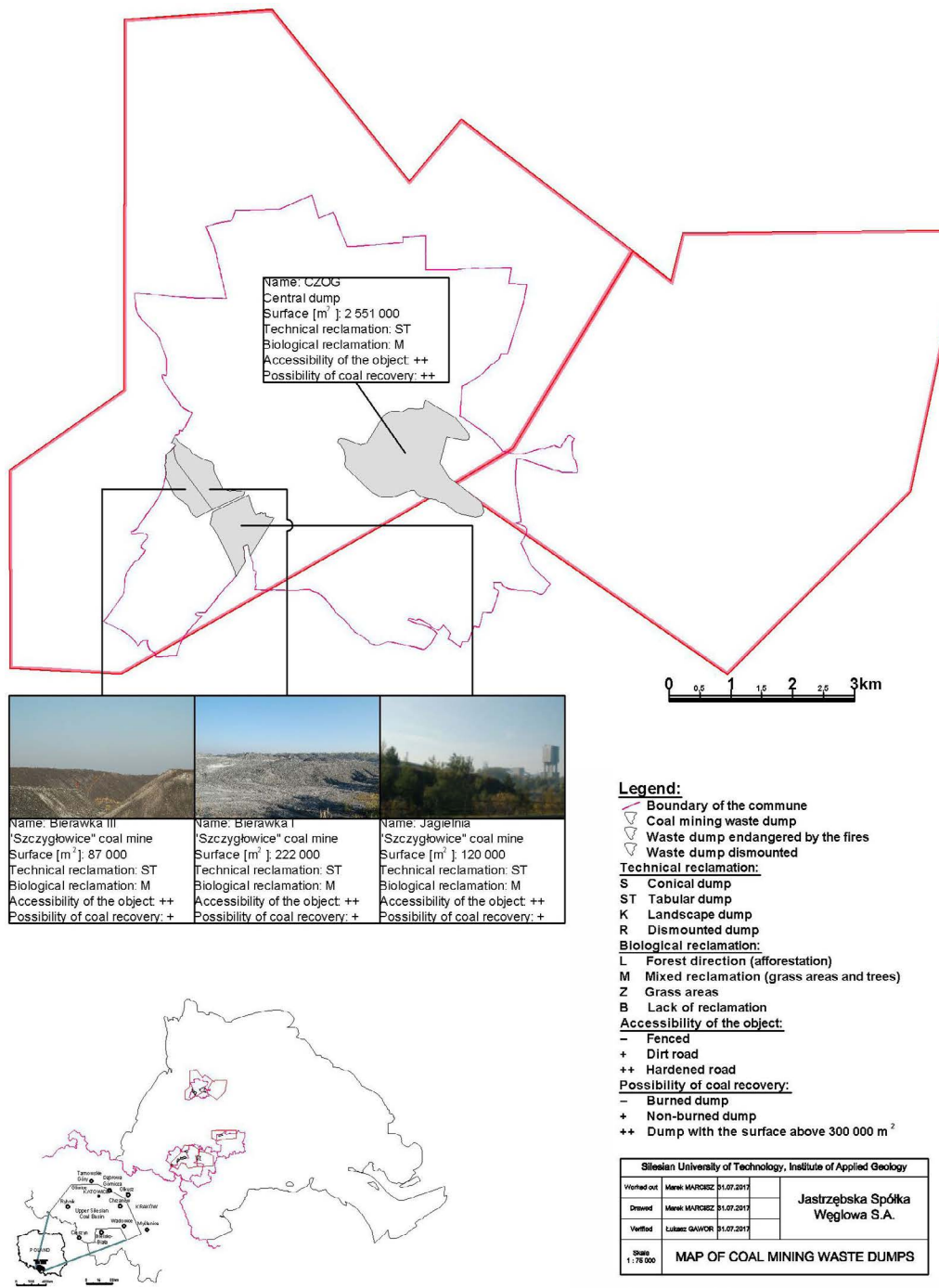


Fig. 4B. Map of coal mining waste dumps

Rys. 4B. Mapa zwałowisk po górnictwie węgla kamiennego

An attempt of defining potential possibilities of coal recovery and connecting of coal quality in the mined deposits through coal mines of JSW SA based on the literature study as well as expected coal in the waste material was carried out on the basis of the collected and elaborated data.

3. Results

An analysis of source materials, verification and inventorization allowed for a characterization of 10 coal mining waste dumps occurring in 4 mines of JSW SA and in 2 belonging to SRK SA, situated in the administrative boundaries in 5 communes of the Silesian Voivodship, the results of which are presented in Table 2.

Of the 10 coal mining waste dumps situated in the boundaries of 5 communes: Mszana, Jastrzębie-Zdrój, Pawłowice, Suszec and Knurów, mining wastes have been disposed by 6 coal mines: Jas-Mos, Zofiówka, Borynia, Pniówek, Krupiński and Szczygłowice. None of the dumps are endangered by fires. The surface varies from 87,000 to 2,551,000 m². There are tabular dumps in a majority of the facilities (7), the rest belong to the category of landscape dumps. Seven dumps represent mixed type of biological reclamation (including afforestation and grass planting), and planted grass has been found on 2 dumps. A majority of the facilities are accessible because there are hardened roads leading to the dumps. The dumps are linked by a dirt road only in three cases, but even this do not make problems with accessibility any smaller. All the facilities are not burned, so there is a possibility of potential coal recovery. As many as 6 facilities represent surface above $30 \cdot 10^4$ m².

The results of field works as photographic material representing different genetic types of the dumps and different reclamation methods and ways use are presented in Fig. 5.

In the reclamation activity, the following types of reclamation can be distinguished:

- ◆ technical – comprising standard ground works – shape of the dump, dewatering design, densification of waste material, agrotechnical works etc.
- ◆ biological – based on proper preparation of the soil (fertilizing), and the proper selection of plant species and their growth (particularly grass planting).

The initial soils originating on waste rocks are characterized by fast disintegration (weathering) and the change of granulation of the surface layer, which is connected mainly with:

- ◆ the presence of coal substance,
- ◆ leaching of alkaline ions,
- ◆ dominance of kaolinite and illite in the mineral composition and connected with this small sorption complex,
- ◆ decomposition of pyrite and high acidity by a dynamically changing pH in the range 7.0–2.5,
- ◆ shortage of nutritive compounds for plants, as e.g. phosphorus and nitrogen (Patrzalek 2006; Patrzalek and Gawor 2008).

Table 2. Coal mining waste dumps after valorization

Tabela 2. Zwaloryzowane zwałowiska odpadów pogórnictwowych

No.	Name	Localization	Coal mine	State	Surface (m ²)	Type of technical reclamation	Type of biological reclamation	Accessibility	Possibilities of coal recovery
1.	Skrzyszów-Wschód	Mszana	Jas-Mos	NZP	100 000	K	M	++	+
2.	Jas-Mos	Mszana, Jastrzębie-Zdrój	Jas-Mos	NZP	627 000	ST	M	++	++
3.	Pochwacie	Mszana, Jastrzębie-Zdrój	Zofiówka	NZP	1 371 000	K	Z	++	++
4.	Borynia-Jar	Jastrzębie-Zdrój	Borynia	NZP	970 000	K	Z	++	++
5.	Kościelnik	Jastrzębie-Zdrój, Pawłowice	Pniówek	NZP	1 936 000	ST	M	++	++
6.	przyzakładowe	Suszec	Krupiński	NZP	707 000	ST	M	++	++
7.	Bierawka I	Knurów	Szczygłowice	NZP	222 000	ST	M	++	+
8.	Bierawka III	Knurów	Szczygłowice	NZP	87 000	ST	M	++	+
9.	Jagielnia	Knurów	Szczygłowice	NZP	120 000	ST	M	++	+
10.	CZOG	Knurów	central dump (zwałowisko centralne)	NZP	2 551 000	ST	M	++	++

Legend:

1. State of the dump: NEF – not endangered by fires.
2. Technical reclamation: L – landscape, D – dismounted, T – tabular.
3. Biological reclamation: F – forest direction (afforestation), M – mixed reclamation (grass areas and trees), G – grass areas, L – lack of reclamation.
4. Accessibility of the object: -- – fenced, + – dirt road, ++ – hardened road.
5. Possibility of coal recovery: -- – burned dump, + – non-burned dump, ++ – dump with the surface above 300 000 m².

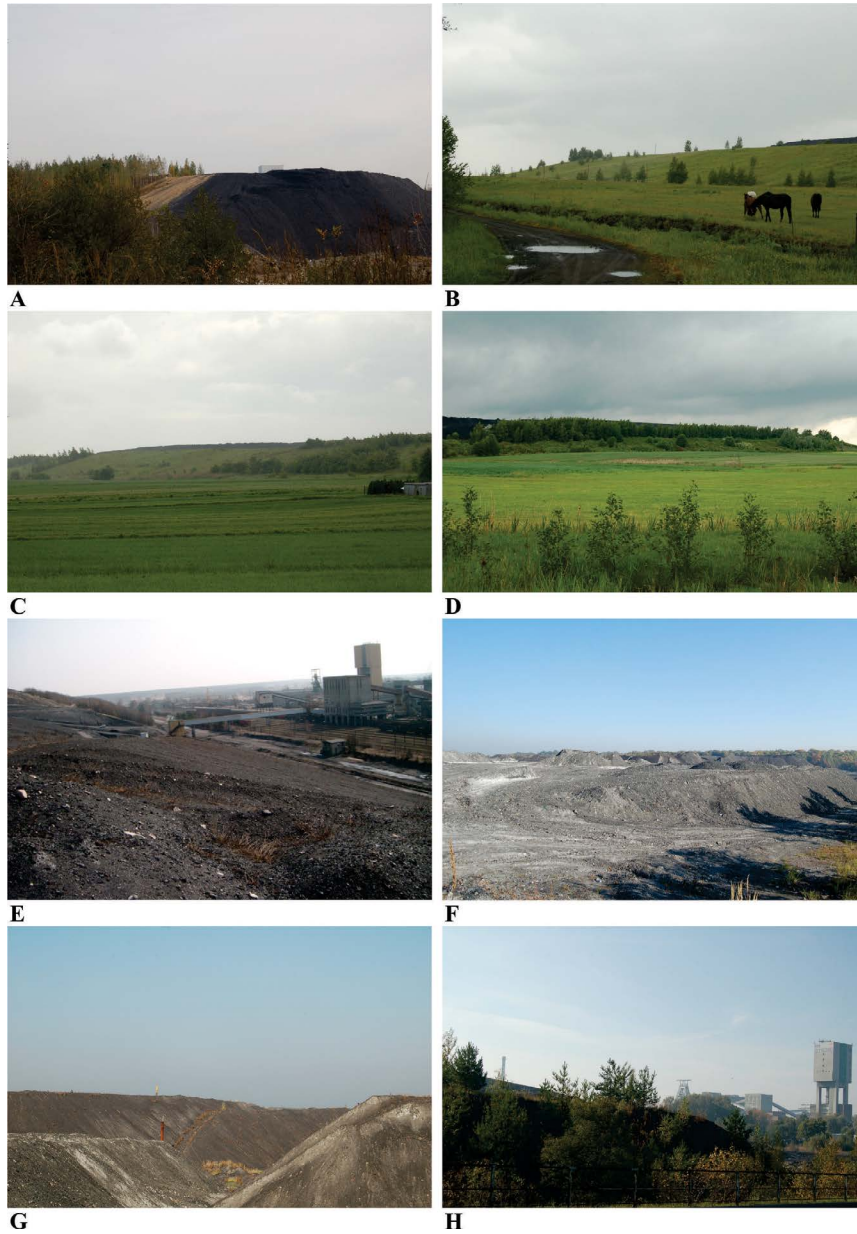


Fig. 5. Photographs of chosen dumps

A – Jas-Mos (Jastrzębie-Zdrój), B – Pochwacie (Jastrzębie-Zdrój), C – Borynia-Jar (Jastrzębie-Zdrój),
 D – Kościelniok (Jastrzębie-Zdrój), E – przyzakładowe (Suszec), F – Bierawka I (Knurów),
 G – Bierawka III (Knurów), H – Jagielnia (Knurów). Phot. Ł. Gawor

Rys. 5. Fotografie wybranych zwałowisk

A – Jas-Mos (Jastrzębie-Zdrój), B – Pochwacie (Jastrzębie-Zdrój), C – Borynia-Jar (Jastrzębie-Zdrój),
 D – Kościelniok (Jastrzębie-Zdrój), E – przyzakładowe (Suszec), F – Bierawka I (Knurów),
 G – Bierawka III (Knurów), H – Jagielnia (Knurów). Fot. Ł. Gawor

Fires of post-mining waste dumps, which hinder or prevent using of these areas may be an important environmental hazard. The dumps did and still undergo fire processes if the sulphur content is higher than 3.0–3.5% and the coal content >10%. Burning dumps cannot be used, but the rock material after burning processes is a valuable raw material, which can be used in road and hydrotechnical engineering works (Gawor 2014; Probiez et al. 2017).

Wastes from coal mining may be used e.g.:

- ◆ directly – as a material in road construction, hydrotechnical works, in underground mining technologies and for the levelling and reclamation of degraded areas,
- ◆ after mechanical preparation in road construction,
- ◆ after thermic preparation for the production of construction materials.

Analysis of the potential possibilities of coal recovery from waste materials consider such parameters as: surface, state of waste material (burned/not burned) and potential coal quality in the waste material. The feasibility study of one dump in the USCB proves that the recovery of coal is economically justified (Gawor 2014). The way of using of recovered coal will generally be combustion.

The technology of preparation of dump material is similar as in the preparation plant of a coal mine. The preparation plant uses the wet preparation method with the application of a dense medium (e.g. magnetite), starting segregation by screening in the grain size classes 1–60 mm and 0.25–1 mm, through the process of beneficiation and the classification of the material in hydrocyclones till the end phase of dewatering in centrifuge (Gawor 2014).

Waste dumps of former Jas-Mos coal mine represent the following: the Skrzyszów-Wschód waste dump and the Jas-Mos waste dump. In spite of a relatively large surface (ca. 727 000 m²), predominant coke coal type, which may be present in the wastes results in the leading of recovery processes becoming possible but disputable regarding defining the market for recovered material. The dump may be foreseen for further tests, considering the possibility of disposing of wastes and including other coal types than coke coal, e.g. from older periods of exploitation.

The Zofiówka coal mine waste dump (Pochwacie waste dump) covers a surface of ca. 1 371 000 m², which makes potential coal recovery possible. The dump covers the third largest surface amongst those analyzed. An additional advantage is the relatively close proximity of other large facilities (e.g. the Kościelniok waste dump). Similarly as in previous case, the dominant coal type in wastes results in the leading of recovery processes becoming economically disputable. The waste dump may also be considered in further tests, taking the possibility of disposing of wastes including other coal types into consideration (www.jsw.pl).

The Borynia coal mine waste dump (Borynia-Jar) with a surface of 970 000 m², considering its surface, could be a facility of potential coal recovery from wastes, although these wastes also include mainly coking coal, therefore the effects of the work of the preparation plant may not be economically justified.

The Pniówek coal mine waste dump (Kościelniok dump) is the second largest dump of the discussed area and one of the largest in the USCB (it covers ca. 1 939 000 m²).

On the condition that there are also other coal types than coking coal in the wastes it can be assumed that this facility is suitable for leading recovery processes. The detailed defining of profitability of coal recovery requires additional research (drilling and laboratory tests).

The Krupiński in Suszec coal mine waste dump (currently given to the Mines Company Restructuring) covers ca. 707 000 m² and is the best facility for leading coal recovery processes. Both the surface of the dump and the coal type (34, semi-soft) as well as the quality of the coal in the wastes make the investment in the preparation plant economically justified, of course by fulfilling all the environmental regulations and standards.

The Knurów coal mine waste dump may be divided into group of three smaller facilities: the Jagielnia, Bierawka I and Bierawka III waste dumps (altogether covering a surface of 429 000 m²) and Central Mining Waste Dump. The first three dumps, if considered together, could be suitable for recovery processes, also coal types (34.2) and coal quality could make recovery economically justified (Marcisz 2004). In the case of a central dump with heterogeneous wastes disposed, their composition (material from different mines with different parameters, particularly power coal) may influence the economical profitability of the investment in the preparation plant and the surface of the dump, the largest in analyzed area and one of the largest in the USCB, is an undoubted asset.

Summary

The results showed that despite the initial information that the majority of the investigated dumps present potential facilities for coal recovery from waste material, this recovery may be economically justified ultimately only in several cases (five facilities). The recovered coal may be used mostly as power coal (in combustion processes) and attempts of using it in briquetting processes have also been made. In most of the facilities, the main factor limiting recovery is the coking coal content in the wastes, although large surfaces result in these facilities possibly becoming the subject of further investigation. There is a very important fact, that none of examined dumps have undergone self-ignition processes and fires in recent times.

Post-mining dumps should undergo reclamation processes, the aim of which is diminishing their inconvenience for the surroundings and creating facilities that will be able to be used for beneficial and social useful activity. This is a complex process, which may be lead parallel with recovery processes and even financed due to the recovery processes.

Reclaimed and managed waste dumps (similar as other mining areas) may and should become both attractive recreation facilities and a characteristic element of the culture landscape of the USCB.

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**VALORIZATION OF COAL MINING WASTE DUMPS FROM
THE MINES OF JASTRZĘBSKA SPÓŁKA WĘGLOWA FOR THE NEEDS
OF RECOVERY OF COAL AND FURTHER RECLAMATION AND MANAGEMENT**

Keywords

Upper Silesian Coal Basin, hard coal, waste dumps, mining wastes, valorization

Abstract

The purpose of the research was mapping, inventorization, and valorization of coal mining waste dumps from the mines of JSW SA company, for the needs of recovery of coal from the dump material as well as the reclamation and management of examined facilities. The valorization of post-mining waste dumps has been carried out using a methodology which considers the problems of reclamation, management, accessibility of the dumps as well as environmental hazards connected with disposing of mining and preparation wastes on the ground surface. An inventorization of 10 coal mining waste dumps coming from 6 mines of JSW SA including in their range 7 deposits: Borynia, Jastrzębie, Zofiówka, Budryk, Knurów, Szczygłowice and Pniówek was carried out. The source material within the localization of particular dumps was obtained from archival materials coming from coal mines and municipalities where the dumps are located. Verified data has been drawn on topographical map, which results in the map of coal mining waste dumps. The results of the valorization of the dumps comprise the defining of: the name of the dump, state of the dump, surface of the dump, accessibility, name of the coal mine from where the wastes come from, type of technical and biological reclamation and possibilities of coal recovery, which have been brought on the drawn map. Basing on collected and elaborated data, an attempt of defining of potential possibilities of recovery of coal from the dumps and connection of coal quality in the deposits of JSW SA and in waste material was made. The results of the research showed that in spite of preliminary information that a majority of the investigated dumps may be considered as potential facilities for coal recovery, ultimately the recovery is economically justified only in several cases (5 facilities).

**WALORYZACJA ZWAŁOWISK ODPADÓW POGÓRNICZYCH Z KOPALŃ
JASTRZĘBSKIEJ SPÓŁKI WĘGLOWEJ SA DLA POTRZEB ODZYSKU WĘGLA
ORAZ PÓŹNIEJSZEJ REKULTYWACJI I ZAGOSPODAROWANIA**

Słowa kluczowe

Górnośląskie Zagłębie Węglowe, węgiel kamienny, zwałowiska, odpady pogórnice, waloryzacja

Streszczenie

Badania miały na celu kartowanie, inwentaryzację oraz waloryzację zwałowisk po górnictwie węgla kamiennego z kopalń JSW SA pod kątem możliwości odzysku węgla ze zwałowisk oraz późniejszej rekultywacji i zagospodarowania badanych obiektów. Waloryzacji dokonano z wykorzysta-

niem autorskiej metodologii, uwzględniającej zagadnienia takie jak: rekultywacja, zagospodarowanie i dostępność, a także zagrożenia dla środowiska, związane z deponowaniem odpadów górniczych i przeróbczych na powierzchni terenu. Dokonano inwentaryzacji 10 zwałowisk odpadów pogórnich pochodzących z 6 kopalń JSW SA obejmujących swoim zasięgiem 7 złóż: Borynia, Jastrzębie, Zofiówka, Budryk, Knurów, Szczygłowice, Pniówek. Dane źródłowe wraz z miejscami lokalizacji poszczególnych zwałowisk pozyskano z materiałów archiwalnych kopalń i urzędów miast, w granicach których występują te zwałowiska (Jastrzębie Zdrój, Knurów, Mszana, Pawłowice, Suszec). Zweryfikowane dane zostały naniesione na podkład topograficzny, czego rezultatem jest mapa zwałowisk odpadów pogórnich. Wyniki waloryzacji zwałowisk, obejmujące określenie: jego nazwy, stanu, powierzchni, dostępności, kopalni, z której pochodzą zwałowane odpady, rodzaju rekultywacji technicznej i biologicznej oraz możliwości odzysku węgla, zostały naniesione na wykonaną mapę. Na podstawie zebranych i opracowanych danych podjęto próbę określenia potencjalnych możliwości odzysku węgla ze zwałowisk oraz powiązania jakości węgla w złożach eksploatowanych przez kopalnie JSW SA i węgla w materiale odpadowym. Wyniki badań wykazały, iż pomimo wstępnej informacji, że większość badanych zwałowisk stanowi potencjalne obiekty odzysku węgla z materiału odpadowego, ostatecznie tylko w kilku przypadkach (5 obiektów) odzysk ten jest ekonomicznie uzasadniony.

