Operating Opencast Mines of Selected Groups in the Silesian Voivodeship Against a Background of Water Environment and Possibilities of Waste Placing

Jarosław STASZCZAK[1)]

[1)] M.Sc., Eng.; Mineral and Energy Economy Research Institute, Polish Academy of Sciences, Krakow; email: jaro@min-pan.krakow.pl

http://doi.org/10.29227/IM-2020-02-55

Submission date: 08-11-2020 | Review date: 29-12-2020

Abstract

The paper is aimed at location identification of operating opencast mines against a background of main groundwater basins (MGB) and in relation to surface waters. The scope of analysis covered the Silesian Voivodeship, as the area in which many operating and closed opencast mines are situated. On the other hand this is a voivodeship, where great amounts of mining waste are generated, potentially placeable in mine workings. The analysis comprised the mines, where raw materials are mined, classified in the Balance of Mineral Deposits Resources in Poland as of 31 December 2017 to the following groups: crushed and block stone, sands and gravels, filling sands, quartz sands for cellular concrete and sand-lime brick production, sands with heavy metals, and moulding sands.

The work resulted in a developed map of mined aforementioned opencast mines arrangement in the Silesian Voivodeship, taking into account their location in relation to groundwater basins boundaries and in relation to surface watercourses. Two distances of mined opencast workings from surface watercourses were taken, 500 m and 1000 m. Such a recognition provides an approximate picture of possibilities for various waste types placing in the process of technical reclamation after the end of mining.

The use of various waste types for technical reclamation is a complex issue, both in the field of regulations applicable to the ground and water environment, in the field of mine location determination, and in the field of the quality of the waste material determination. The applied legal regulations, frequently changing over time, indicate the right process of decision making and handling of individual waste types. It is most important, that raw materials and waste intended to fill the mines would not create a hazard for the environment, including the environment of surface waters and ground waters.

Keywords: *opencast mines, MGB area, surface waters, reclamation, waste*

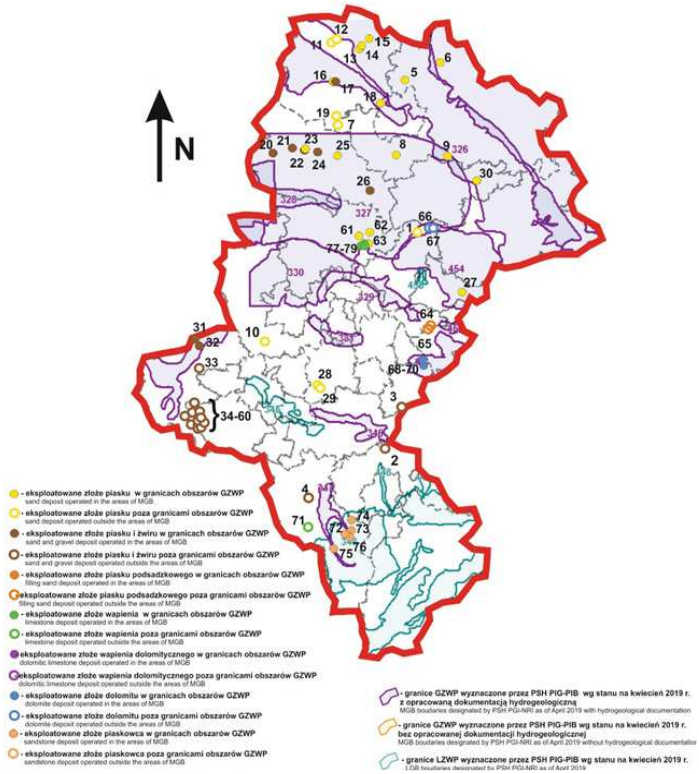
Introduction

The paper is aimed at identification of active opencast mines location against a background of main groundwater basins (MGB) and in relation to surface waters. The scope of analysis covered the Silesian Voivodeship, as the area in which many operating and closed opencast mines are situated. On the other hand this is a voivodeship, where great amounts of mining waste are generated, potentially placeable in mine workings. The paper is a continuation of previous papers with the author's involvement 'Active opencast mines of carbonate raw materials against a background of MGB boundaries and possibilities of their reclamation by filling with waste' (Klojzy-Karczmarczyk, Staszczak, 2017) and 'Recognition of sand and gravel pits in relation to MGB boundaries and surface watercourses in the area of Silesian Voivodeship' (Klojzy-Karczmarczyk, Staszczak, 2019).

The analysis comprised the mines, where raw materials are mined, classified in the Balance of Mineral Deposits Resources in Poland as of 31 December 2017 (Szuflicki et al (ed.) 2018) to the following groups: crushed and block stone, sands and gravels, filling sands, quartz sands for cellular concrete and sand-lime brick production, sands with heavy metals, and moulding sands. Not all raw materials from the mentioned groups are mined in the Silesian Voivodeship. Only crushed and block stone (limestone, dolomite, dolomitic limestone, and sandstone), sands and gravels, and also filling sands were mined in 2017. No quartz sands for cellular concrete and sand-lime brick production, sands with heavy metals, and moulding sands were mined.

The work resulted in a developed map of mined aforementioned opencast mines arrangement in the Silesian Voivodeship, taking into account their location in relation to groundwater basins boundaries and in relation to surface watercourses. Such an identification provides an approximate picture of possibilities for various waste types placing in the mine. It is necessary to note here that the waste placement in mines, considered in the paper, can be carried out in the process of technical reclamation after the end of mining. The original intention of the paper consisted in locating operating opencast mines against a background of MGP protection area boundaries. However, because of the lack of published sufficient and topical materials the mines in question were situated only against a background of MGP boundaries.

The use of various waste types for technical reclamation is a complex issue, both in the field of regulations applicable to the ground and water environment, in the field of mine location determination, and in the field of the quality of the waste material determination. The applied legal regulations, frequently changing over time, indicate the right process of decision making and handling of individual waste types (e.g. Góralczyk, Baic, 2009; Góralczyk, 2011; Kukulska-Zając, Dobrzańska, 2012; Klojzy-Karczmarczyk, Mazurek, 2015; Kicki, Sobczyk, 2016, Klojzy-Karczmarczyk, Staszczak 2019). The provisions of the Act of 14 December 2012 on Waste are applied to reclamation and management of opencast mines with the use of waste in the process of recovery. The filling of a post-mining working with external materials is the basic stage of technical phase of reclamation in rock mines (Ostrę-



Rys. 1. Lokalizacja złóż surowców badanych grup w województwach południowej Polski (Szuflicki i in., 2018) na tle granic zbiorników wód podziemnych (stan na kwiecień 2019 r., wykorzystano mapę GZWP wykonaną przez PSH PIG-PIB; http://epsh.pgi.gov.pl/epsh/)

Fig. 1. Location of raw materials deposits of the studied groups in the voivodeships of southern Poland (Szuflicki et al, 2016) in relation to the boundaries of groundwater basins (as of April 2019, with the use of the MGB map developed by PHS PGI-NRI; http://epsh.pgi.gov.pl/epsh/)

ga, Uberman, 2010; Strzałkowski, Kaźmierczak, 2014; Czekaj, Sobczyk, 2015) and the use of materials for mines filling is limited to certain waste groups or types.

Previous analyses show that selected mining waste fractions with codes 01 01 02 and 01 04 12 can be widely used in technical reclamation by opencast mines filling. This material frequently has no waste status and is a raw material (Klojzy-Karczmarczyk et al, 2016a, b. Klojzy-Karczmarczyk, Staszczak 2019). It is most important, that raw materials and waste intended to fill the mines would not create a hazard for the environment, including the environment of surface waters and ground waters.

Methodology adopted in the analysis

Based on the data contained in the Balance of Mineral Deposits Resources in Poland (Szuflicki et al (ed.) 2018) a list was prepared of all operated in 2017 opencast mines of crushed and block stone (dolomites, limestones, dolomitic limestones, and sandstones), sands and gravels, filling sands, quartz sands for cellular concrete and sand-lime brick production, sands with heavy metals, and moulding sands deposits in the area of Silesian Voivodeship. The opencast mines were next situated on an orthophotomap (http://www.geoportal.gov.pl), from which geographical coordinates of facilities were read, which were then imposed on the map of MGB boundaries in the area of Poland, produced by the National Hydrogeological Service of the National Geological Institute – National Research Institute (PSH PIG-PIB) as of April 2019 (http://epsh.pgi.gov.pl/epsh/, 2019). As a result a map of all mined opencast mines was obtained for deposits of aforementioned groups in the Silesian Voivodeship. The carried out analysis did not include mines not operated in 2017.

The map produced by the PSH PIG-PIB comprises all documented, not documented main and local groundwater basis (http://epsh.pgi.gov.pl/epsh/, 2019) and their range was marked out on the basis of determined uniform qualitative and quantitative parameters of basins (Mikołajków & Węglarz 2011).

To estimate distances of opencast mines analysed in the paper from watercourses the generally available base maps were used of the Google portal (https://www.google.com/maps) and of the geoportal (https://www.geoportal.gov.pl). River channels are not straight lines therefore in certain cases doubts appeared, whether a specific mine is situated at a distance of less than 500 m, or not. Finally, a decision was made to classify mines to the group of less than 500 m, if only a minimal their part was situated closer than 500 m from the river channel boundary.

Results of carried out analysis

The management of opencast mines after the end of mining is a still observed problem. However, there are more and more methods of reclamation and management, proving the dynamics of this research area development. The prepared map (Fig. 1) presents only opencast mines of the above groups mined now within the Silesian Voivodeship. Altogether 79 mined deposits (as of 2017 end) of sands and gravels, filling sands, sandstones, limestones, dolomites, and dolomitic limestones are situated within the voivodeship area. The total number of such deposits is much higher. The total number of all deposits of discussed groups in the Silesian Voivodeship,

Tab. 1. Lokalizacja wyrobisk odkrywkowych badanych grup złóż w powiatach województwa śląskiego w odniesieniu do granic GZWP
Tab. 1. Location of opencast mines of studied deposit groups in the districts of the Silesian Voivodeship in relation to MGB boundaries

Powiat *District*	Ilość wyrobisk / Ilość na obszarze GZWP *Number of opencast mines / number in the MGB area*	***[Nr wyrobiska odkrywkowego - zgodnie z ryc. 1]***, Nr GZWP, wiek utworów*, typ ośrodka** (wg A.S. Kleczkowski, 1990), status udokumentowania*** ***[No. of opencast mines** - according to Fig. 1**]**, No. of MGB, age of aquifer*, type of aquifer (according to A.S. Kleczkowski, 1990)**, documentation status****
Sands and gravels, filling sands		
Będzin	1/0	-
Bielsko-Biała	1/0	-
Bieruń-Lędziny	1/0	-
Cieszyn	1/0	-
Częstochowa	5/4	**[5]** 326, J_3, s-k, U; **[6]** 408, Cr_3, s, U; **[8]** 327, T_1, T_2, s-k, U; **[9]** 326, J_3, s-k, U; 327, T_1, T_2, s-k, U;
Gliwice	1/0	-
Kłobuck	9/6	**[13]** 326, J_3, s-k, U; **[14]** 326, J_3, s-k, U; **[15]** 326, J_3, s-k, U; **[16]** 325, J_2, s-k, U; **[17]** 325, J_2, s-k, U; **[18]** 325, J_2, s-k, U;
Lubliniec	7/7	**[20]** 327, T_1, T_2, s-k, U; **[21]** 327, T_1, T_2, s-k, U; **[22]** 327, T_1, T_2, s-k, U; **[23]** 327, T_1, T_2, s-k, U; **[24]** 327, T_1, T_2, s-k, U; **[25]** 327, T_1, T_2, s-k, U; **[26]** 327, T_1, T_2, s-k, U;
city of Dąbrowa Górnicza	1/1	**[27]** 454, T_1,T_2, s-k, U;
city of Jaworzno and city of Sosnowiec	2/0	-
Mikołów	2/0	-
Myszków	1/1	**[30]** 326, J_3, s-k, U;
Racibórz	7/2	**[31]** 332, Tr, Q_K, p, U; **[32]** 332, Tr, Q_K, p, U;
Tarnowskie Góry	3/3	**[61]** 327, T_1, T_2, s-k, U; **[62]** 327, T_1, T_2, s-k, U; **[63]** 327, T_1, T_2, s-k, U;
Wodzisław	17/0	-
Wodzisław and Racibórz ****	6/0	-
other districts	0/0	-
Total voivodeship	**65/24**	
Crushed and block stone		
Będzin	2/0	-
Bieruń-Lędziny	3/3	**[68]** 452, T1, T2, s-k, U; **[69]** 452, T1, T2, s-k, U; **[70]** 452, T1, T2, s-k, U;
Cieszyn	6/5	**[72]** 348, Cr_f, s-p, L; **[73]** 348, Cr_f, s-p, L; **[74]** 348, Cr_f, s-p, L; **[75]** 347, Q_D, p, U; **[76]** 348, Cr_f, s-p, L;
Tarnowskie Góry	3/3	**[77]** 327, T_1, T_2, s-k, U; **[78]** 327, T_1, T_2, s-k, U; **[79]** 327, T_1, T_2, s-k, U;
other districts	0/0	-
Total voiodeship	**14/11**	
TOTAL	**79/35**	

** – Aquifer age based on the Regulation of the Council of Ministers (Dz.U. Of 2006, No 126, item 878)*
*** – Aquifer types: s – fissured, p – porous, s–k – fissured-karstic, s–p – fissured-porous*
**** – Degree of MGB documentation: U – MGB with prepared of hydrogeological documentation,*
N – MGB without prepared hydrogeological documentation (as of April 2019, http://epsh.pgi.gov.pl/epsh)
***** – deposits in the area of both districts.*

Tab. 2. Lokalizacja wyrobisk odkrywkowych badanych grup złóż w odniesieniu do cieków powierzchniowych na obszarze województwa śląskiego
Tab. 2. Location of opencast mines of studied deposit groups in relation to the watercourses in the Silesian Voivodeship

Województwo *Voivodeship*	Ilość wyrobisk / Ilość w odległości **do 500 m** od cieków *Number of opencast mines / up to 500 m from watercourses*		Ilość wyrobisk / Ilość w odległości **do 1000 m** od cieków *Number of opencast mines / up to 1000 m from watercourses*	
Sands and gravels, filling sands				
Total voivodeship	**65/24**		**65/48**	
	watercourse name	number of mines	watercourse name	number of mines
	Oder	14	Oder	25
	Biała Przemsza	2	Biała Przemsza	3
	Other	8	Liswarta	3
			Biała Oksza	3
			tributary of Gostynka	2
			Vistula	2
			Other	10
Crushed and block stone				
Total voivodeship	**14/4**		**14/12**	
	watercourse name	number of mines	watercourse name	number of mines
	Brennica	2	Brennica	3
	Gahura	1	tributary of Brynica	3
	Leśnica	1	tributary of Przemsza	3
			Other	3

comprising the mined deposits, deposits with preliminary explored resources (in cat. C2 + D), deposits with resources explored in detail (in cat. A + B + C1), deposits which mining was already abandoned, deposits cancelled from the balance of resources in the reporting year, and managed deposits, mined periodically, is 395. Sands and gravels are the largest group (288 deposits), moulding sands are the next group (45 deposits), crushed and block stone (44 deposits), filling sands (17 deposits), and quartz sands (1 deposit) (Szuflicki et al, (ed.) 2018). After the end of mining each mine should be technically reclaimed. The application of external raw materials or various types of waste to fill the mines is possible for all basic target reclamation directions (agriculture, forest, recreation, and construction). The choice of reclamation direction depends mainly on hydrogeological and location conditions, area development situation, conditions of zoning plans, or financial capabilities.

The location conditions of operating opencast mines in the area of the Silesian Voivodeship were identified, for which in the future there is a potential possibility of carrying out technical reclamation (by filling and shaping the surface) using the waste from hard coal mining or other waste or raw materials. The discussed mined deposits (Szuflicki et al (ed.) 2018) are situated in the area of 16 districts (Table 1). The largest number of them is in the Wodzisław district (17 deposits), Kłobuck district (9 deposits), and also in Cieszyn, Lubliniec, and Racibórz districts (7 deposits each). In addition, mined deposits of the aforementioned raw materials are situated in the Tarnowskie Góry (6 deposits), Częstochowa (5 deposits), Bieruń-Lędziny (4 deposits), Będzin (3 deposits), Mikołów (2 deposits), and Bielsko-Biała, Gliwice, Myszków districts and in the city of Dąbrowa Górnicza (1 deposit each). The remaining deposits are situated at boundaries of two districts. In the areas of Wodzisław and Racibórz dis-

Tab. 3. Zestawienie wyrobisk odkrywkowych badanych grup złóż w powiatach województwa śląskiego z uwzględnieniem ich lokalizacji na tle granic GZWP oraz w odległości od cieków powierzchniowych

Tab. 3. Summary of opencast mines of studied deposit groups in the districts of the Silesian Voivodeship in relation to MGB boundaries and at a distance from surface watercourses

Powiat *Dictrict*	Ilość wyrobisk *Number of opencast mines*				
	ogółem *Total*	na obszarze GZWP *within MGB area*	do 500 / 1000 m od cieków *up to 500 / 1000 m from watercourses*	poza GZWP i ponad 500 m od cieków *outside the MGB and above 500 m*	poza GZWP i ponad 1000 m od cieków *outside the MGB and above 1000 m*
Sands and gravels, filling sands					
Będzin	1	0	0/1	1	0
Bielsko-Biała	1	0	0/1	1	0
Bieruń-Lędziny	1	0	1/1	0	0
Cieszyn	1	0	1/1	0	0
Częstochowa	5	4	0/1	1	0
Gliwice	1	0	1/1	0	0
Kłobuck	9	6	1/5	3	1
Lubliniec	7	7	0/2	0	0
city of Dąbrowa Górnicza	1	1	1/1	0	0
city of Jaworzno and city of Sosnowiec	2	0	2/2	0	0
Mikołów	2	0	1/2	1	0
Myszków	1	1	0/0	0	0
Racibórz	7	2	5/5	1	1
Tarnowskie Góry	3	3	0/1	0	0
Wodzisław	17	0	10/17	6	0
Wodzisław and Racibórz ****	6	0	1/6	5	0
other districts	0	0	0/0	0	0
Total voivodeship	**65**	**24**	**24/47**	**19**	**2**
Crushed and block stone					
Będzin	2	0	0/1	2	1
Bieruń-Lędziny	3	3	0/3	0	0
Cieszyn	6	5	4/5	1	0
Tarnowskie Góry	3	3	0/3	0	0
other districts	0	0	0/0	0	0
Total voivodeship	**14**	**11**	**4/12**	**3**	**1**
TOTAL	**79**	**35**	**28/59**	**22**	**3**

**** – *deposits in the area of both districts.*

tricts (6 deposits), and in the area of cities of Jaworzno and Sosnowiec (2 deposits).

In the other districts there are no mined deposits of described raw material groups (Table 1, Fig. 1). As many as 35 out of 79 mined deposits are situated within boundaries of main groundwater basins (MGB). The largest group of mined deposits are those of sand and gravel – 37, of which 7 are situated within MGB boundaries. In addition, 26 mined sand deposits were located (16 in MGB area), 5 sandstone deposits (all within MGB), 4 dolomite deposits (2 in MGB areas), 4 limestone deposits (2 within MGB), 2 filling sand deposits (all outside MGB area), and 1 dolomitic limestone deposits (in the MGB area). No sand and moulding sand pits were located in the area of Silesian Voivodeship. Groundwater basins within boundaries, in which opencast mines are mined, are situated in geological structures varying in terms of age (Table 1).

Overall, at a distance below 500 m from surface watercourses there are 28 mined opencast mines, and at a distance of less than 1000 m – already 60 out of 79 mined opencast mines of raw material groups analysed in this paper (Table 2) in the area of Silesian Voivodeship. However, if we consider the intersection of opencast mines location outside the MGB area and situated at least 500 m from the nearest watercourse, the number of facilities satisfying this criterion will be only 22 out of 79 mined opencast mines, and if the criterion of distance from rivers to 1000 m, then only 3 out of 79 (Table 3).

Summary and conclusions

The mined opencast mines of groups: crushed and block stone (limestones, dolomites, dolomitic limestones, sandstones), sands and gravels, filling sands, quartz sands, and moulding sands in the Silesian Voivodeship are situated in 16 districts. They were arranged on the map of MGB boundaries of Poland produced by the National Hydrogeological Service, National Geological Institute – National Research Institute (http://epsh.pgi.gov.pl/epsh/, 2019). As a result of carried out analysis of operating opencast mines location for deposits of studied groups against a background of MGB boundaries it was found, that out of 35 facilities among 79 opencast mines are situated within boundaries of determined MGB areas, which is approx. 44% of the total. In the crushed and block stone group 11 out of 14 opencast mines are situated in the MGB area, which is as much as 78%. In turn, in the group of filling sands and gravels this percentage is much smaller – 37%. 24 out of 65 opencast mines are situated in MGB areas in this group.

Because of the scale of sands and gravels output, and also of crushed and block stones, and the necessity of post-mining sites reclamation, the possibility to manage various waste types in the process of workings filling is an interesting development direction. However, it is necessary to emphasise that nearly a half of them are situated within the range of main groundwater basins areas. In the protection

areas of groundwater basins, being a part of aquifer feeding, bans, orders, and limitations in the land use are being applied.

If we add the second criterion, such as the distance from watercourses equal to 500 metres, these requirements will be met by only 22 out of 79 mined opencast mines, which is less than 28%, and if we increase the criterion of distance from rivers to 1000 metres, only 3 opencast mines will remain and less than 4% of all mined ones. Only 3 facilities, out of 14 opencast mines of the crushed and block stone group, are situated outside the MGB area and at a distance of more than 500 m from surface watercourses. If we extend the criterion from 500 to 1000 metres, the conditions will be met by only 1 opencast mine, which is 7% of the total. In turn, 19 facilities, out of 65 opencast mines of the filling sands as well as sands and gravels group, are situated outside the MGB area and at a distance of more than 500 m from surface watercourses. If we extend the criterion from 500 to 1000 metres, the conditions will be met by only 2 opencast mines, which is 3% of the total.

Although in the presented paper the opencast mines of described deposit groups are situated against a background of MBG boundaries, and not boundaries of their protection zones, the developed map provides an approximate picture of possibilities of placing various waste types in the mines. It should be emphasised, that the process of opencast mines reclamation by filling with waste or with another external material each time should be preceded by a detailed recognition of hydrogeological conditions and hydrological conditions of the analysed area. In addition, in sensitive areas a proper choice of waste, from the point of view of their quality and potential transformation of the chemical composition over time, is particularly important.

Praca została wykonana w ramach prac statutowych Instytutu Gospodarki Surowcami Mineralnymi i Energią Polskiej Akademii Nauk

The study was carried out under the statutory work of the Mineral and Energy Economy Research Institute of the Polish Academy of Sciences

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Eksploatacja kopalni odkrywkowych wybranych grup w województwie śląskim na tle środowiska wodnego i możliwości składowania odpadów

Celem pracy jest rozpoznanie lokalizacji czynnych wyrobisk odkrywkowych na tle granic głównych zbiorników wód podziemnych (GZWP) oraz w pobliżu cieków wodnych. Obszarem badań zostało wybrane województwo śląskie jako obszar, na którym znajduje się wiele czynnych oraz nieczynnych wyrobisk, a także bardzo duża ilość potencjalnych możliwych do ulokowania w wyrobiskach odpadów górniczych. Analizie poddano wyrobiska, w których eksploatowane są surowce zaklasyfikowane w Bilansie zasobów złóż kopalin w Polsce wg stanu na 31 XII 2017r., do grup: kamienie łamane i bloczne, piaski i żwiry, piaski podsadzkowe, piaski kwarcowe do produkcji betonów komórkowych i cegły wapienno-piaskowej, piaski z metalami ciężkimi oraz piaski formierskie.

Efektem pracy jest opracowana mapa rozmieszczenia eksploatowanych w/w wyrobisk w województwie śląskim z uwzględnieniem ich lokalizacji w stosunku do granic zbiorników wód podziemnych oraz w stosunku do cieków powierzchniowych. Przyjęto dwie odległości eksploatowanych wyrobisk odkrywkowych od cieków powierzchniowych, które odpowiednio wynoszą 500 m. oraz 1000 m. Takie rozpoznanie daje przybliżony obraz możliwości lokowania różnych rodzajów odpadów w procesie rekultywacji technicznej po zakończeniu eksploatacji.

Zastosowanie różnego rodzaju odpadów w celu rekultywacji technicznej jest zagadnieniem złożonym zarówno w sferze przepisów odnoszących się do jakości środowiska gruntowo-wodnego, jak i w zakresie określenia lokalizacji. Surowce oraz odpady przeznaczone do wypełniania wyrobisk nie powinny stanowić zagrożenia dla środowiska.

Zakłady górnicze posiadające poeksploatacyjne wyrobiska odkrywkowe, które w przyszłości będą przeznaczone do rekultywacji, mogą stanowić poważną grupę odbiorców kruszyw lub odpadów produkowanych nie tylko w sektorze górnictwa węgla kamiennego. Głównymi kryteriami decydującymi o możliwości rekultywacji wyrobisk odpadami są opłacalność i założenia środowiskowe.

Słowa kluczowe: *kopalnie odkrywkowe, obszar GZWP, wody powierzchniowe, rekultywacja, odpady*