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The influence of mineral commodities coming from wastes on industrial minerals' markets in Poland

Key words

Minerals markets, industrial wastes, mineral waste raw materials, substitutes

Abstract

The paper presents sources of industrial wastes, which can be used as substitutes of primary minerals. Legal and economic factors influencing such use, are considered. Significance of mineral waste raw materials in the minerals management in Poland is analysed. Important applications of industrial wastes as sources of substitutes for industrial and construction minerals, as well as their influence on markets of these minerals, are reviewed in detail.

Introduction

For centuries, primary raw materials coming from mineral deposits have the dominant importance on mineral commodities markets. However, due to some environmental, technological and economic reasons, the significance of secondary sources (including wastes) has been continuously increasing, especially since the beginning of the 1990s. Such secondary and waste materials have increasing importance in the management of various types of mineral commodities and should be taken into account in minerals markets analyses. Their significance is diversified depending on type of mineral commodity (i.e. it is not the case for

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fuels, except of alternative fuels from wastes). For some minerals, the share of commodities produced from secondary and waste sources in total supply may approach 10—20%, sometimes even 50% (gypsum).

Raw materials from secondary sources may possess quality parameters comparable to parameters of raw materials obtained from primary sources, being their substitutes of full value. Frequently such raw material is a substitute of not full value, but it can compete due to very competitive price. Another very common situation is when mineral wastes find application (e.g. for ground levelling), but they cannot be regarded as mineral commodity (they do not possess such features as commodity turnover, quality standarisation, etc.). The newly introduced environmental law regulations in Poland are expected to result in intensification of industrial wastes utilisation. It does and will strongly influence the markets of some mineral commodities. This paper illustrates these phenomena providing examples of important applications of industrial wastes as sources of substitutes for industrial and construction minerals.

1. Industrial wastes as source for mineral waste raw materials production

The total amount of industrial wastes generated in Poland declined from 144 million t in 1990 to 118 million t in 2002. Amount of utilised wastes grew from 77 million t (54%) to 93 million t (79%), respectively. The majority of these wastes are generated in the three southern voivodeships: Śląskie (37%), Dolnośląskie (26%), and Małopolskie (8%) (Environmental Protection 2002). The majority of industrial wastes (total of 78% in 2002) is generated in mining and processing, power plants and smelters.

1.1. Wastes from mining and processing

Wastes from mining and processing are the largest group of wastes generated and deposited in Poland. In 2002, ca. 68 million t of mining and processing wastes were generated, what makes ca. 58% of total amount of wastes generated during economic activity. The total amount of mining and processing wastes deposited on dumps achieved 1500 million t, i.e. 73% of total tonnage of wastes deposited (Environmental Protection 2002). The three main sources of such wastes are: mining and processing of hard coal, mining and processing of non-ferrous metals ores, rock minerals extraction.

In the hard coal industry, almost 36 million t of wastes were generated in 2002, and 32 million t of them were utilised. The majority of them (over 90%) is obtained during processing in jiggers, heavy liquids and slurry circulation. Flotation wastes make 6% of total amount, while mining wastes make the rest. High level of economic utilisation of hard coal industry wastes is reported (ca. 90%). However, only ca. 30% of wastes are utilised in industrial application, while over 70% for ground levelling and other engineering works (National Waste Management Plan 2003).

In the non-ferrous metals ore mining and processing, almost 30 million t of wastes was generated in 2002, and 23 million t of them was utilised. Flotation wastes from copper ores processing constitute a majority of them (ca. 90%). Flotation wastes from Zn-Pb ores processing make under 10%, while mining wastes only 1%. Economic utilisation of this wastes significantly rose, but primarily due to formal reasons. 75—78% of flotation wastes from copper ores processing has recently started to be used as material in hydrotechnical engineering, i.e. for construction of barriers and sealing of the Żelazny Most settling pond (Jasiński et al. 2003).

Wastes coming from rock minerals extraction constitute the third important source of mineral waste in this group. The volume of these wastes generated and utilised, reported by the Central Statistical Office, are substantially underestimated. According to this official information, generation of wastes from rock minerals mining amounts to below 3 million tpy, and the majority of them are utilised (Environmental Protection 2002). However, it is estimated, that total volume of these wastes exceeds 10 million tpy, while the level of their utilisation does not exceed 40%. There is a lack of detailed information about it, and estimates are based on information from "Balance of mineral waste raw materials from mining and power plants" published by the Institute of Waste Management in 1996, as well as on information coming from MIDAS database at the Polish Geological Institute. Wastes obtained during extraction and processing of such rocks as: limestone, dolomite, sandstone, magmatic rocks, clays, sand and gravel, etc., are classified into this group (Balance of mineral waste raw materials... 1996; Balance of mineral deposits... 2004).

1.2. Wastes from power plants

Wastes generated in course of fuels burning in power plants and central heating plants are the second important group of industrial wastes. In 2002, ca. 17 million t of wastes from power plants were generated, what makes 14% of total amount of industrial wastes obtained. Over 70% of these wastes were utilised. The total amount of wastes from power plants deposited on dumps approached 330 million t (Environmental Protection 2002). The main wastes of this group are: furnace slag from hard coal or brown coal combustion, fly ash from hard coal or brown coal combustion, ash & slag mixes, cenospheres from fly ash, wastes from desulphurisation by wet lime methods, wastes from desulphurisation by semidry and dry methods, mixtures of fly ash and desulphurisation products, etc. The largest amounts are generated in case of: ash & slag mixes (8.1 million t in 2002, i.e. 47%), fly ash (4.0 million t, 24%), furnace slag (2.3 million t, 14%), and — lately — wastes from desulphurisation by wet lime methods (2.6 million t, 15%). In the coming years, due to introduction of new techniques of coal combustion, amount of traditional slag and ash should diminish, while ca. 4 million tpy of sulphate-calcium ashes from fluidised-bed combustion will be generated (National Waste Management Plan 2003; Galos 2003).

1.3. Wastes from steelworks and non-ferrous metals smelters

Wastes from metallurgical processes are one of the most important wastes generated by industry. In 2002, ca. 7.5 million t of such wastes were obtained, what makes 6% of total amount of industrial wastes generated. 6.3 million t of these wastes (84%) were utilised (Environmental Protection 2002). The main types of metallurgical wastes are:

— in steelworks — primarily steel-making and blast furnace slag, also melting losses, slimes and dusts from gases cleaning, iron sulphate; total quantity 4.5—5.0 million tpy, 85% is utilised;

— in copper smelting — mainly shaft furnace and converter slag (95%), also dusts and slimes from gases cleaning and melting losses; total quantity ca. 1.3 million tpy, 75% is utilised;

— in zinc smelting — primarily shaft and rotary furnace slag, also slimes from gases cleaning and melting losses; total quantity ca. 0.17 million tpy, over 98% is utilised.

2. Legal and economic factors influencing intensification of utilisation of industrial wastes as raw materials

In developed countries, implementation of low-waste or no-waste technologies of production is the most preferred method of waste management. When such wastes are or have to be generated, their utilisation should have the largest importance, while their deposition is much less preferred. Such approach was also implemented in the Waste Management Act in Poland. System of fees for wastes deposition is one of the steps to achieve such aim. These fees are assumed to stimulate reduction of amount of wastes generated, to increase economic utilisation of wastes being produced, as well as to supply ecological funds with financial means. Share of environmental fees in the total production costs is significant, e.g. 0.5—1.5% in hard coal mines, 0.05—0.7% in power plants, under 0.5% in steelworks (Górka 1997). Currently, two types of deposition fees are used in Poland. Fee for waste location in the dump, which depends on types of waste, represents the first type. Examples of such location fees for the most important wastes from mining and processing, power plants and metallurgy, according to the latest "Ordinance of the Cabinet on fees for use of environment", are listed in Table 1. Second type of fee — storage fee — is used only for wastes, which can be economically utilised. So, some types of wastes are excluded of such fee — e.g. hard coal processing wastes, non-ferrous metals processing wastes, ash & slag mixes from power plants. Storage fee rates for other wastes commonly constitute annually 3% of location fee for such waste.

Other economic instruments of waste management — product fees, deposit systems — were also introduced on the basis of the Waste Management Act and the Act on containers and containers' wastes. However, within the scope of mineral raw materials, they are implemented only in case of metallic and glass containers (product fee with minimum

TABLE 1

Location fees for the most important wastes from mining and processing, power plants and metallurgy

TABELA 1

Opłaty za umieszczenie odpadów górniczych, przeróbczych, energetycznych i metalurgicznych na składowisku odpadów

Type of waste	Location fee [zł/t]
Mining wastes from metallic ores extraction	14.75
Other mining wastes	9.51
Non-ferrous metals ores flotation wastes	8.39
Rock minerals processing wastes	9.51
Hard coal processing wastes	8.77
Furnace slag, ash & slag mixes and fly ash from coal burning	14.75
Wastes from desulphurisation	8.77
Mixes of fly ash and wastes from desulphurisation	13.57
Blast furnace and steelmaking slag	14.75
Lead-bearing and zinc-bearing slag	47.35
— except of zinc-bearing granulated slag from shaft and rotary furnaces	14.75
Copper-bearing slag	14.75
— except of copper-bearing granulated slag from shaft furnaces	9.51

Source: Ordinance of the Cabinet of 18^{th} March 2003 on fees for use of environment

recycling levels), and batteries (deposit fee). In practice, they are not applicable for wastes, which are potential sources of industrial and construction minerals or their substitutes.

Implementation of technologies allowing for economic utilisation of wastes is usually expensive. However, growth of industrial wastes utilisation allows to limit waste deposition fees, to reduce area necessary for dumps, and to prolong period of dump exploitation. Moreover, production of substitutes of primary minerals on the basis of wastes allows to protect more reserves of primary minerals for future generations. Unfortunately, up till now a majority of environmental investment regarding waste management in companies generating industrial wastes, as well as the majority of ecological funds expenses, are assigned for construction and operation of waste dumps. Only small expenses are spent for preventing of wastes generation, for implementation of low-waste or no-waste technologies of production, or for utilisation of wastes.

Possibilities of usage of industrial wastes as raw materials were emphasised by the "Ordinance of the Minister of the Economy on qualification of wastes, which should be used for industrial purposes and on conditions of their use". It prompted to develop substitution of natural raw materials by waste raw materials, as well as to develop other applications of wastes. Such wastes can be used if they can substitute natural raw material, find use instead of natural raw material in the technological process, or be a source of raw materials to be recovered. The majority of wastes from mining and processing (waste code 01), wastes from power plants (code 1001), and a large part of wastes from steelworks and non-ferrous metals smelters (codes 1002—1006) are regarded as such wastes. Though the level of industrial wastes utilisation in Poland is continuously increasing, extent of their utilisation as substitute of primary raw materials is still — in some cases — unsatisfied. Common lack of knowledge of modern technologies enabling production of raw materials from wastes, as well as still poor environmental consciousness of companies' management and the whole society, are the main reasons of such situation. Of course, there is also a lot of positive examples regarding this problem. Utilisation of practically all synthetic gypsum from flue gas desulphurisation, or almost all wastes generated in course of fuels burning in power plants (now even called "coal combustion products" — not wastes), are the best examples.

3. Significance of mineral waste raw materials in the minerals management in Poland

The share of mineral waste raw materials in the domestic management of mineral commodities is diversified. They can be used as substitutes of full value for primary mineral commodities, e.g. crushed aggregates made of steelmaking or converter slag, synthetic gypsum from flue gas desulphurisation, metals manufactured from scrap. In some cases, raw materials obtained from wastes are substitutes of not full value, being reportedly cheaper, e.g. feldspar-quartz raw materials from granite processing, kaolin cake from glass sand washing. Mineral waste raw materials can be used as components of input for the production of mineral commodity in the broad sense, e.g. wastes from mining and power plants for production of cement clinker, cement, building ceramics, cellular concrete, etc. Such waste materials can also be used — partly or entirely — instead of primary mineral commodities in the technological process, which bases on such raw materials. The examples are: wastes from hard coal mining and from power plants used in backfilling instead of filling sand, cullet instead of primary raw materials for glass containers production, spent refractories instead of some part of raw materials input for new refractories production.

Mineral waste raw materials are or can be potentially used in the coming years as substitutes for ca. 30 types of primary mineral raw materials. Metallic scrap, especially scrap of non-ferrous metals and iron scrap, have traditionally the largest importance. Share of scrap in the total domestic supply of some metals is substantial: over 50% for lead (together with lead from spent lead-acid batteries), 30% for aluminium, 10—15% for iron and steel, up to 10% for copper, 3—8% for zinc, 2—3% for silver (Lewicka 2003b). Cadmium, nickel and magnesium metals and alloys are also obtained from scrap. On the contrary, gold and platinum group metals are recovered primarily from spent catalysts (Minerals Yearbook of Poland 1998—2002).

Mineral commodities obtained from wastes have the growing importance as substitutes of industrial minerals and construction minerals. They find use e.g. as substitutes of various types of aggregates, clays and primary materials for binding materials production. They have also some significance on markets of feldspar raw materials, Ca and Ca-Mg fertilisers, raw materials for glass production and for refractories, as well as backfilling materials. The most important applications of industrial wastes as sources of substitutes of industrial minerals and construction minerals, are characterised in the consecutive chapter.

4. Important applications of industrial wastes as sources of substitutes for industrial and construction minerals

4.1. Crushed aggregates

Crushed aggregates are commonly obtained from solid rocks by their extraction, crushing and classification. However, an increasing share of crushed aggregates is currently produced from various mineral wastes. The most important of them are:

— wastes from dimension stone production;
— wastes from production of industrial limestone and dolomite (partly voluntary production, partly from rocks of lower quality);
— wastes from gravity separation of Zn-Pb ore (waste dolomite);
— wastes from hard coal mining and processing (self-burned coal shale);
— wastes from iron & steel industry — converter slag, other steelmaking slag, blast furnace slag;
— wastes from non-ferrous metals industry — shaft furnace slag.

Polish dimension stone industry is based mainly on granite and sandstone deposits. Only a part of extracted rock is suitable for production of dimension stone in the form of blocks and slabs, as well as of road stone (pitcher, curbs). Rock wastes coming from production of these assortments can find use as materials for crushed aggregates production. However, only a part of them is processed into aggregates. It is quite well developed in case of granite, where probably over 1 million tpy of such material is processed into granite crushed aggregates.

Total mining output of limestone for cement and lime production amounts to ca. 35 million tpy in recent years, but in the last three years it dropped to only ca. 28 million tpy due to reduction of cement clinker production by 26%. Almost 70% of total output is consumed for cement and lime production, over 25% — for production of limestone rock for sale, while a few % (1.5—2.0 million tpy) — for limestone crushed aggregates production. Only some cement and lime producers use some amounts of limestone for crushed aggregates production, primarily in the following plants: "Kujawy" (Lafarge), "Miedzianka" (Nordkalk), and "Trzuskawica" (CRH). Some part of aggregates production bases on limestone of lower quality (e.g. with high Mg content), but partly it is voluntary production of companies aiming to increase their revenues by development of additional products. In case of industrial dolomite, two companies are currently operating deposits of such a dolomite useful for steelworks and refractories: GZD Siewierz and KiPD "Żelatowa" in Chrzanów. Due to drop of industrial dolomite sales, both companies developed production of dolomite crushed aggregates. In sum, their deliveries of aggregates amount to ca. 0.7 million tpy, which constitute ca. 30% of their mining output. For crushed aggregates production, dolomite of quality inappropriate for smelter and refractory grades production is mainly used.

Waste dolomite rock from gravity separation of Zn-Pb ore is the another waste source for crushed aggregates production. Such material is delivered by two zinc-lead mines west of Kraków (ZGH "Bolesław", ZG "Trzebionka") and processed by them, as well as by another neighbouring plants. Total amount of generated waste dolomite in these two plants amounted to ca. 2.8 million t in 2002, while production of dolomite aggregates on their basis was estimated at ca. 2.0 million t.

Aggregates from self-burned coal shale (shale gravelite aggregates) are commonly of lower quality in comparison to aggregates from compact rocks or from metallurgical slag. They are currently manufactured on the basis of old dumps of coal shale (auto-burned) by several companies in Upper Silesia, e.g. "Renova" Ltd. Pszów, "Renobud" Bytom, "Gwarex Ryan Poland" Ltd. Katowice, "Haldex" Ltd. Katowice, "Tercharpol" Czeladź, and others. Their combined production is estimated to be 1.5—2.0 million tpy (Minerals Yearbook of Poland 1998—2002).

Aggregates from metallurgical slag started to be important raw materials, seriously competing with crushed aggregates made of compact rocks, regarding quality and price. Their quality is sometimes even better than quality of some crushed aggregates (e.g. some limestone aggregates). Their production is difficult to ascertain, but it increased significantly in recent few years. Aggregates from blast furnace slag are the most important, but aggre- gates from converter slag and similar steelmaking slag — being better quality — have also some importance. "Slag Recycling" Ltd. of Kraków, utilising the slag dumps of the Sendzimir Steelworks in Cracow, is the most important producer of this type of aggregates. Its production dynamically rose to over 1.5 million tpy in the last years (Smakowski, Galos 2001). The older slag dump of the Sendzimir Steelworks is also utilised — since 1996 — by "Madrohut" Co., which delivers up to 0.8 million tpy of such aggregates."Alexander Mill Services" Ltd. with plants in Warszawa, Stalowa Wola, Zawiercie and Bytom is also very important supplier. Its production rose from under 1.0 million t in 1998 to 1.55 million t in 2002. The others operate primarily near Upper Silesian steelworks, e.g. "HK Eko-Grys" Ltd. in Dąbrowa Górnicza (slag from Katowice steelworks), "Łabędy" Smelter in Gliwice, "Ehazet" Ltd. in Katowice (material from Częstochowa and Florian steelworks, and Łaziska smelter), as well as in the vicinity of Opole — "Behatex-Plus" in Ozimek (material from Ozimek Smelter). Such aggregates are also manufactured on the basis of shaft furnace slag from copper smelters in Głogów and Legnica. Slag from Głogów smelter is currently processed by unit of "KGHM Metale" S.A. (new installation opened in 2004 with capacity

1.5 million tpy). Slag from Legnica smelter is still processed by production unit of Kopalnie Surowców Skalnych of Złotoryja S.A. at level of ca. 0.25 million tpy. Minor production comes from "Miasteczko Śląskie" Smelter (ca. 0.1 million tpy). Deliveries of crushed aggregates from metallurgical slag are limited primarily to Upper Silesia and Kraków regions only (Minerals Yearbook of Poland 1998—2002). Their total production is estimated to be ca. 6.0—6.5 million tpy, though production reported by the Central Statistical Office amounted to 2.7 million t in 2002 and 4.3 million t in 2003.

Total production of crushed aggregates, manufactured both of compact rocks and various types of waste materials, is estimated to amount ca. 33 million t in 2002. However, share of crushed aggregates made of wastes is continuously increasing in Poland, now achieving almost 40% (Table 2). Unfortunately, manufacture of such aggregates is geographically limited to southern Poland, as it is in the case of "primary" crushed aggregates (crushed aggregates made of compact rocks extracted for crushed aggregates production). Location of producers of crushed aggregates made of solid rocks is a result of site of these rocks deposits, while in case of aggregates from wastes it depends on location of wastes sources. Especially intensive competition between crushed aggregates from wastes and crushed aggregates made of compact rocks is observed in the Upper Silesia-Kraków region, where market share of crushed aggregates from wastes can achieve even 70%.

TABLE 2

Estimated share of crushed aggregates from various sources in their total production in Poland (2002)

TABELA 2

Szacunkowy udział kruszyw łamanych z poszczególnych źródeł w ich łącznej produkcji w Polsce (2002)

Type of crushed aggregates	Share in total domestic production [%]
Primary crushed aggregates[1]	59
Crushed aggregates from processing of dimension stone production wastes	3
Crushed aggregates from production of industrial limestone	5
Crushed aggregates from production of industrial dolomite	2
Crushed aggregates made of waste dolomite rock from gravity separation of Zn-Pb ores	6
Crushed aggregates made of wastes from hard coal mining and processing	5
Crushed aggregates made of various type of slag from steelworks	18
Crushed aggregates made of slag from nonferrous metals smelters	2

[1] Crushed aggregates made of compact rocks extracted for crushed aggregates production.

4.2. Lightweight aggregates

Lightweight aggregates produced by thermal processing are currently obtained from expanding clays and from fly ash. First type of such aggregates, i.e. gravelite[1] from clays, is currently produced by two companies: "Optiroc Gniew" Ltd. in Gniew near Gdańsk, and PKL "Keramzyt" Ltd. in Mszczonów near Warszawa. Their combined production currently amounts to ca. 250,000 tpy. Second type — ash gravelite — is manufactured primarily by "Pollytag" S.A. of Gdańsk, which produces 90,000—110,000 tpy of such aggregates under trade name *pollytag*, utilising a significant portion of fly ash from the nearby "Wybrzeże" Power Plant. Similar production is carried on at much lower level in few other plants: *pregran* in Skawina, *stargran* in Stargard Gdański, *cegran* in Łódź, *megran* in Poznań, *epogran* in Opole, etc. They use only a small portion of fly ash obtained in the adjacent power plants (the rest is commonly used for the manufacture of cellular concrete products). The combined production of ash gravelite is estimated at the level of ca. 130,000—140,000 tpy, what makes 35% share in domestic supply of lightweight aggregates. To develop use of ash gravelite, it is necessary to prepare wide offer of products based on this aggregate, as it was done by Optiroc in case of gravelite.

4.3. Feldspar-quartz raw materials

Research on possible use of fine-grained material from granite processing was carried on in Poland since the 1970s. A few technologies, which would allow to obtain high quality feldspar-quartz flour on the basis of these materials, were developed (Nowak 2002). Some trials of their introduction were reported in the half of the 1990s, but without success. Rapid development of Polish ceramic tiles industry resulted in quick growth of demand for feldspar-quartz raw materials. The low price of such materials was one of the main requirements for their use. That is why domestic plants manufacturing coloured ceramic tiles started to use feldspar-quartz materials even with high Fe_2O_3 content (up to 2%). As a result, since the second half of the 1990s the Wrocławskie Mineral Mines Co. (a subsidiary of Tarmac) has become the important domestic fedspar-quartz commodities supplier. The company is selling granite sand 0—2 mm and powder 0—1 mm generated in course of crushed aggregates production at the Graniczna mine, as rich in alkalis low-biotite quartz-feldspar raw materials. They are obtained both from current production of aggregates, and from old dumps of these fine-grained materials. They are successfully utilized in the ceramic industry for the production of tiles in such plants as Opoczno, Paradyż, Tubądzin, Pilch, Nowa Gala, etc. The sale of these assortments to the ceramic sector has been increasing gradually, up to 83,700 t in 2002 (Lewicka 2003a). It constituted up to 20% of the domestic market of feldspar-quartz raw materials for ceramic tiles.

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[1] This product is known in Poland as *keramzyt*.

4.4. Kaolin

For years, KSM "Surmin-Kaolin" (currently owned by Amberger Kaolinwerke GmbH) was the predominant producer of various grades of kaolin in Poland. It produces washed kaolin from poorly compact kaolinitic sandstone, containing 16—22% of kaolinite. However, in the last ten years, production of lower grades of kaolin was developed by the main glass sand producers, on the basis of clayey wastes from glass sand washing. Such wastes, previously dumped, started to be recovered in three glass sand plants. Clayey fraction after sand washing is directed to thickener, where after adding of coagulant, kaolin slime is precipitated. Then it is directed to filter press, where *kaolin cake* (low quality kaolin grade) is obtained. However, quality of such kaolin is variable, with significant content of Fe_2O_3 (even up to 2%). On the opposite, it is cheap grade, readily used for the production of some ceramic tiles. Currently such kaolin grade is manufactured by two producers in central Poland:

— KPK "Grudzeń Las" Ltd. — in Grudzeń Las plant at the level of 23,000—32,000 tpy, currently the second plant of the company in Zajączków-Syski started so additional production of kaolin cake is expected;

— TKSM "Biała Góra" Ltd. — in Tomaszów plant from line of kaolin filter cake commenced in 2001, where kaolin production rose to 32,500 t in 2003.

The third glass sand producer — KiZPPS "Osiecznica" (owned by Quarzwerke) — directs kaolinitic waste material after sand washing to "Surmin-Kaolin" processing plant, where it is thoroughly processed into high quality kaolin grades, in parallel to kaolin grades obtained from "Surmin-Kaolin" own material. As a result, 25,000—30,000 tpy of kaolin grades originating from "Osiecznica" material are produced. They are also primarily sold to ceramic tiles industry (Minerals Yearbook of Poland 1998—2002).

Total consumption of kaolin grades in ceramic tiles industry is estimated to be ca. 110,000—120,000 tpy in recent years. Ca. 60,000 tpy comes from "Grudzeń Las" and "Biała Góra" plants, located nearby main ceramic tiles plants in central Poland. Consecutive ca. 25,000 tpy of kaolin for ceramic tiles originate from "Osiecznica" kaolinitic material, processed and sold by "Surmin-Kaolin". It means, that over 60% of needs of domestic ceramic tiles industry for kaolin is currently met by by-product obtained during glass sand washing.

4.5. Gypsum

Synthetic gypsum, obtained from flue gas desulphurization (FGD) installations in power plants, is a very important substitute for gypsum rock, having similar properties and applications. Its production in Poland started in September 1994 with the commissioning of the first installation at the "Bełchatów" power plant. Before this date, domestic production of gypsum raw materials was predominated by two gypsum rock mines near Pińczów (south of Kielce, central Poland), with minor share of two anhydrite mines in southwestern Poland. In the following years, consecutive installations for wet limestone desulphurisation were commenced (Table 3). As a consequence, production of synthetic gypsum rose from zero in 1993 to over 1.1 million t in 2000 (Galos, Szlugaj, 2001), with some stagnation at this level in the last years. Total capacity of these installations amounted to ca. 1.35 million tpy in 2003, but their average utilization stood at ca. 81% in the same year (Table 3).

TABLE 3

FGD gypsum producers in Poland

TABELA 3

Producenci gipsu syntetycznego z odsiarczania w Polsce

Power plant	Year of commencement	Capacity in 2003 ['000 t]	Estimated capacity utilization in 2003 [%]
Bełchatów	1994	600	92
Jaworzno III	1996	120	71
Opole	1997	170	88
Konin	1997	40	75
Połaniec	1999	100	85
Łaziska	2000	100	84
Dolna Odra	2001	60	97
Kozienice	2001	160	32
Total		**1 350**	**81**

Source: Galos et al. 2003, producers' data

Mainly due to development of FGD gypsum production, total production of gypsum raw materials in Poland, after a drop to 0.8 million tpy in the beginning of the 1990s, increased to 2.2—2.4 million tpy in recent years. Simultaneously, the share of FGD gypsum in total domestic gypsum raw materials supplies increased from zero in 1993 to 48—50% in recent years. This share of FGD gypsum can even rise in the coming years, as next new installations will be constructed in "Bełchatów" power plant (increase of capacity to 750,000 tpy). Moreover, such installations will be constructed in "Pątnów II" and — maybe — also "Skawina" power plants, so total domestic capacities of FGD production can achieve ca. 1.5 Mtpy (Minerals Yearbook of Poland 1998—2002). It is worth mentioning that recently practically all FGD gypsum generated in desulphurisation installations in Poland find industrial application (it is not the case in some other countries manufacturing FGD gypsum, e.g. Germany).

Significance of FGD gypsum as gypsum raw material is not equal in each application. It is partly a consequence of long-term contracts between suppliers and users of this raw material. It is estimated that in recent years FGD gypsum constitute ca. 60—65% of gypsum raw materials used in gypsum binders production, while in case of gypsum plasterboards this share amounts to 60—70%, and for the cement production — 45—50%.

4.6. Substitutes of primary raw materials for cement clinker and cement production

Waste raw materials of various types have increasing importance in the production of cement clinker and cement in Poland. At the stage of cement clinker production, main waste raw materials finding application, are: fly ash from power plants, limestone rock wastes, iron-bearing wastes (siderite siftings, steelmaking dust, iron-bearing dust and slime, converter slag) and other wastes (clay shale from hard coal mining, furnace slag from power plants, blast furnace slag, etc.). At the stage of cement production (mainly Portland cements, Portland cements with additives, and metallurgical cements), the main consumed waste raw materials are as follows: blast furnace slag, fly ash from power plants, FGD gypsum (see also point 4.5), and silica fume (The Polish Cement..., 2003). Record level of wastes usage was achieved in 2000, when 1.31 million t of various wastes were used for cement clinker production, while 2.87 million t — for cement production (Table 4). Level of waste usage in cement clinker and cement production decreased in the last three years as a result of 25% decrease of cement production. However, share of waste raw materials in input for clinker production rose from 10% in 2000 to 13% in 2003, while in case of cement production — from 17% to 20%, respectively. This tendency should be continued. Expected growth of cement production in the coming years will result in the significant increase of amount of wastes consumed by this industry, even up to 5 million tpy in sum.

TABLE 4

The main waste raw materials used for cement clinker and cement production in Poland ['000 t]

TABELA 4

Główne surowce odpadowe użytkowane do produkcji klinkieru cementowego i cementu w Polsce [tys. t]

Type of waste raw material	2000	2002
Limestone rock wastes	340	620
Fly ash	1,408	1,193
Blast furnace slag	1,250	1,146
FGD gypsum	274	245
Iron-bearing wastes	241	176
Others	380	307
Total	**3,893**	**3,687**

Source: The Polish Cement and Lime Association

4.7. Other important wastes substitutes of industrial and construction minerals

There is a lot of other industrial wastes (not mentioned in the previous points), usage of which can significantly influence level of consumption of some primary industrial and construction minerals. The most important of them are:

— waste substitutes of clays in building ceramics and cellular concrete production;

— substitutes of filling sand in backfilling.

In recent years, fly ash from power plants and central heating plants have increasing importance in the production of building materials. Probably over 1 million tpy of such wastes is currently used for this purpose. In building ceramic industry, many manufacturers — especially in southern Poland — utilize fly ash as additional component (25—40% of batch). However, in some cases fly ash constitute up to 80% by weight of the technological batch mix (Brylska et al. 2001). Utilisation of fly ash in building ceramics is estimated at ca. 250,000 tpy (Galos, Uliasz-Bocheńczyk 2004). Lower quantities of slag and ash & slag mixes, as well as of clayey wastes from hard coal and lignite mines, are also used to manufacture building ceramics (provided they meet the requirements, particularly in respect to radioactivity and heavy metal content).

Production of cellular concrete products for building construction has been recently increasing in Poland, up to over 3.5 million m^3py. Currently, 32 cellular concrete plants are operated by 27 companies (Minerals Yearbook of Poland 1998—2002). Nine of them use fly ash from the nearby power plants or heating plants in their production (Łagisza, Bielsko-Biała, Kozienice, Łódź, Ostrołęka, Reda, Skawina, two plants in Warsaw); the remaining 23 plants utilize natural quartz sand. Current usage of fly ash amounts to ca. 0.5 million tpy (Brylska et al. 2001).

The utilization of various wastes from hard coal mining and processing, as well from power plants, as substitutes of filling sand in backfilling in Upper Silesia hard coal mines, is continuously growing. It is estimated that the combined level of their utilization rose from ca. 1 million tpy in the early 1990s to ca. 4 million tpy in recent years. Their share in the total tonnage of materials used for backfilling in these mines probably exceeds 50%, while level of consumption of filling sand in this area decreased by over 60% in the same period. Increasing usage of wastes from power plants (including desulphurisation products) was especially reported. In the other important area of underground mining — KGHM Polish Copper mines in Legnica-Głogów area — only natural sand is used as backfilling material. However, if research on use of flotation wastes from copper ore processing as component of solidified filling material will be successful, usage of such type of wastes in backfilling can achieve even a few million tpy (Jasiński et al. 2003).

Certainly, there are much more interesting examples of wastes utilization for the production of industrial and construction minerals or their substitutes. Few of them are worth mentioning: kaolinitic clays from old dumps near closed mines; gravel and mixes from industrial sand mines; fertilisers from fine grained wastes in limestone and dolomite mines;

spent refractories as secondary raw materials for the production of new magnesite, chamotte and fused alumina-zircon refractories; various chrome-bearing wastes for production of chromium compounds (Galos 2003).

Conclusions

Mineral waste raw materials have increasing importance in the management of numerous mineral commodities, being substitutes of primary minerals. They have traditionally the largest importance in case of metallic commodities, but their position on the markets of some industrial and construction minerals is also remarkable. The largest influence of such waste raw materials is reported on markets of crushed aggregates, gypsum, kaolin for ceramic tiles and raw materials for cement clinker and cement production. It is worth mentioning that a high percentage of wastes from power plants and from metallurgy is utilised for production of raw materials or finished construction products. It is not the case for wastes from mining and processing. Majority of them is utilised, but primarily for ground levelling, hydrotechnical engineering or backfilling.

To limit the amount of deposited industrial wastes, system of fees for wastes deposition is used in Poland: fee for waste location in the dump — applicable for all wastes with various rates, and annual fee for storage — used only for wastes, which can be economically utilised. Qualification of wastes, which should be used for industrial purposes, prompted to develop substitution of natural raw materials by waste raw materials, as well as other applications of wastes. Common lack of knowledge of modern technologies enabling production of raw materials from wastes, as well as still poor environmental consciousness of companies and the whole society, are the main reasons of still unsatisfactory extent of industrial wastes utilisation as substitute of primary raw materials. On the contrary, utilisation of all FGD gypsum and almost all coal combustion products, are important examples of good practice in the area of wastes management.

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KRZYSZTOF GALOS

WPŁYW ODPADOWYCH SUROWCÓW MINERALNYCH NA RYNKI NIEMETALICZNYCH SUROWCÓW MINERALNYCH W POLSCE

Słowa kluczowe

Rynki surowcowe, odpady przemysłowe, mineralne surowce odpadowe, substytuty

Streszczenie

Artykuł omawia źródła odpadów przemysłowych, które mogą być użyte jako substytuty surowców pierwotnych. Analizie poddane zostały czynniki prawne i ekonomiczne, które wpływają na rozwój tej substytucji. Przedstawiono znaczenie mineralnych surowców odpadowych w gospodarce surowcami mineralnymi w Polsce. Szczegółowej analizie poddano ważne zastosowania odpadów przemysłowych jako substytutów surowców budowlanych i ceramicznych, oraz ich wpływ na rynki tych surowców.