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MARKET ANALYSIS OF SELECTED RAW MATERIALS FOR THE CERAMIC AND GLASS INDUSTRIES IN POLAND OVER THE YEARS 1990–2012

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Introduction

Raw materials for the ceramic and glassmaking industries belong to the wide group of industrial minerals. In terms of accessibility to sources of these raw materials in Poland there can be distinguished three groups:

1. Raw materials of local importance (utilized in the vicinity of mines):
   - clays for building ceramics,
   - sand for sand-lime wares and cellular concrete,
   - limestone for the production of cement and lime.
2. Raw materials of national importance, both of domestic and foreign origin:
   - kaolin,
   - ceramic clays, e.g. white-firing, stoneware and refractory clays,
   - feldspar and feldspar-quartz raw materials,
   - quartz sand of glass grade,
   - limestone and dolomite for the production of glass-grade flour ,
   - quartz, industrial quartzite and quartz-schist,
   - industrial dolomite,
   - gypsum and anhydrite.
3. Raw materials exclusively of foreign origin, in the absence of their domestic sources of appropriate quality, e.g.:
   - zirconium raw materials,
   - andalusite and related raw materials,
   - graphite,
   - magnesite and magnesia (calcined, dead-burned and fused)*,
   - bauxite and alumina (non-metallurgical),
   - talc and pyrophyllite.

The scope of this study includes selected, primary mineral raw materials for glassmaking and ceramics *sensu stricto*, i.e. fine, technical, and refractory ceramics, excluding special ceramics, e.g. decorative one. Raw materials listed in the first group, as well as gypsum and anhydrite from the second group are the basic raw materials for the building materials industry, and therefore they are not discussed here. The glassmaking industries as well as fine, technical and refractory ceramics, consume principally raw materials belonging to the

* Raw magnesite from the sole domestic mine is utilized in other applications than glassmaking and ceramics.

second and third groups (with the exception of gypsum and anhydrite – as previously noted). Taking into account possible options of satisfying the demand for these raw materials, the presented work has been divided into two parts:

— Part 1 examines mineral raw materials originating both from domestic and foreign sources, i.e.: kaolin, ceramic clays (white-firing, stoneware and refractory clays), glass-grade quartz sand, quartz and industrial quartzite, feldspar and feldspar-quartz raw materials, limestone for the glassmaking industry, as well as industrial dolomite for the production of glass and refractories;
— Part 2 analyzes mineral raw materials totally scarce, that have to be imported to cover the demand of the ceramic industry, i.e.: andalusite and related raw materials, zirconium raw materials, graphite, magnesite and magnesia (calcined, dead-burned and fused), bauxite and alumina (non-metallurgical). Talc and pyrophyllite has not been examined as ceramics is of minor importance among their numerous and diverse applications in Poland and the volume of their consumption in ceramics is difficult to ascertain.

1. Raw materials of national importance from domestic and foreign sources

1.1. Kaolin

Almost entire mine production of kaolin in Poland has come from the deposit of kaolinite sandstone – Maria III located in the Lower Silesia. Since 2003 some negligible output has also originated from Dunino deposit, the raw material of which has been classified as basalt weathering of kaolinite type. In the 1990s the mining output of kaolin varied from 215,000 to 290,000 tpy, while in the first decade of the 2000s – from 250,000 to around 350,000 tpy. Most recently (2010–2012) it ranged from 240,000 to 280,000 tpy, reaching maximum volume in 2011 (Tab. 1).

Washed kaolin has been also recovered from quartz sand and sandstone deposits located in the synclines of Bolesławiec (Osiecznica II deposit) and of Tomaszów (Biała Góra, Grudzeń Las, and Unewel deposits), in course of wet processing of the raw material that has been carried out in order to remove of the finest grains.

In the first half of the 1990s the total domestic production of washed kaolin oscillated around 50,000 tpy (Lewicka 2004). Since 1994, through the subsequent 10 years, it was gradually increasing, approaching almost 160,000 tpy (Tabs. 1–2). This growth was fuelled by dynamic rise of demand in the ceramic industry, particularly the ceramic tile sector, the capacity of which had been expanded in unprecedented pace. At the same time, kaolin consumption in the paper industry dropped significantly owing to the switch of the paper manufacturing technology from kaolin to cheaper fillers – precipitated or ground calcium carbonate. This resulted in a change in the structure of kaolin consumption, which has been dominated by ceramic grades, in the majority utilized for ceramic tiles manufacturing. The share of these grades in total kaolin supplies increased from 45% in the first half of the 1990s to 85–90% after 2000, with small and diminishing importance of non-ceramic grades, i.e. paper (3–4% in recent years) and others (4.5–7%) (Tab. 2). The second half of the past decade has brought variations in domestic supplies of kaolin, which exhibited a distinct reduction from 156,000 tons in 2008 to merely 125,000 tons in 2010 due to the fall in demand for ceramic goods, especially tiles and sanitaryware, in the construction industry. In the last two years, however, as some positive signs of recovery in the construction industry have appeared, kaolin supplies increased to 164,000 and 138,000 tpy, respectively.

Table 1

Kaolin management in Poland [‘000 t]

Tabela 1

Gospodarka kaolinem w Polsce [tys. t]

Category/Year	1990	1991	1992	1993	1994	1995	1996	1997
Mining output *	215.0	233.0	229.0	265.0	294.0	269.0	281.0	262.0
Total production, including:	48.1	44.1	42.4	47.9	49.3	50.8	59.4	69.7
*KSM Surmin-Kaolin***	*36.9*	*41.9*	*33.7*	*37.1*	*40.7*	*39.8*	*47.0*	*52.8*
Grudzeń Las	–	–	–	*4.7*	*5.7*	*6.3*	*7.7*	*12.7*
TKSM Biała Góra	–	–	–	–	*0.7*	*1.4*	*2.0*	*2.0*
Ekoceramika	–	–	–	–	*0.9*	*1.7*	*2.0*	*1.6*
Imports	97.5	58.0	62.8	65.3	86.4	81.5	45.4	45.8
Exports	–	–	1.0	1.8	9.9	10.9	0.1	0.2
Apparent consumption	145.6	102.1	104.2	111.4	125.8	121.4	104.7	115.3

Category/Year	1998	1999	2000	2001	2002	2003	2004	2005
Mining output *	276.0	286.0	344.0	267.0	252.0	340.1	351.0	326.0
Total production, including:	69.2	80.3	89.9	101.2	113.6	133.3	157.4	156.7
KSM Surmin-Kaolin **	*57.9*	*53.9*	*53.0*	*62.4*	*74.1*	*73.4*	*71.9*	*79.0*
Grudzeń Las	*6.8*	*22.7*	*31.8*	*27.2*	*22.9*	*30.3*	*29.4*	*33.9*
TKSM Biała Góra	*2.5*	*1.4*	*1.7*	*8.9*	*16.3*	*29.5*	*56.0*	*43.7*
Ekoceramika	*1.6*	*1.8*	*3.0*	*2.5*	–	–	–	–
Imports	43.6	47.2	48.4	61.3	70.2	72.1	80.2	83.0
Exports	0.7	3.3	1.8	6.3	3.8	11.6	9.6	5.6
Apparent consumption	112.1	124.2	136.5	156.2	179.9	193.8	228.0	234.1

Category/Year	2006	2007	2008	2009	2010	2011	2012
Mining output *	297.0	319.0	318.0	261.0	238.0	285.2	249.1
Total production, including:	144.4	153.2	155.9	136.0	124.6	163.6	137.8
KSM Surmin-Kaolin **	*75.1*	*84.1*	*85.7*	*73.8*	*69.1*	*87.0*	*70.3*
Grudzeń Las	*35.6*	*46.1*	*50.7*	*46.9*	*41.7*	*60.4*	*53.5*
TKSM Biała Góra	*33.7*	*22.9*	*19.4*	*15.3*	*13.8*	*16.2*	*14.0*
Ekoceramika	–	–	–	–	–	–	–
Imports	88.3	113.6	123.9	89.3	107.7	118.9	120.0
Exports	6.3	10.0	8.0	11.6	8.0	12.8	11.1
Apparent consumption	226.4	256.8	271.8	213.7	224.3	269.7	246.7

* Mining output of kaolinite sandstone from Maria III deposit, since 2003 – also from Dunino deposit (100–300 tpy).
** Including grades obtained from residues after quartz sand washing in the Osiecznica mine.
Source: Mineral Resources Datafile... 2013, producers’ data, Central Statistical Office (GUS)

Table 2

The structure of kaolin production in Poland [‘000 t]

Tabela 2

Struktura produkcji kaolinu w Polsce [tys. t]

Category/Year	1990	1991	1992	1993	1994	1995	1996	1997
Total production, including:	48.1	44.1	42.4	47.9	49.3	50.8	59.4	69.7
Ceramic and glass grades	*30.8*	*20.0*	*26.7*	*22.2*	*22.6*	*29.0*	*35.9*	*55.0*
Ceramic tile grades	*NA*	*NA*	*NA*	*7.0*[e]	*8.0*[e]	*10.0*[e]	*22.0*[e]	*26.0*[e]
Paper grades	*4.4*	*4.6*	*5.9*	*9.7*	*14.4*	*7.8*	*7.6*	*5.8*
Other grades	*12.9*	*18.5*	*9.8*	*9.9*	*12.2*	*14.0*	*15.9*	*8.9*

Category/Year	1998	1999	2000	2001	2002	2003	2004	2005
Total production, including:	69.2	80.3	89.9	101.2	113.6	133.3	157.4	156.7
Ceramic and glass grades	*54.7*	*66.8*	*73.8*	*89.3*	*101.0*	*114.5*	*132.0*	*135.2*
Ceramic tile grades	*32.0*[e]	*42.0*[e]	*50.0*[e]	*65.0*[e]	*78.3*	*89.3*	*110.2*	*115.0*
Paper grades	*6.3*	*4.7*	*6.2*	*2.9*	*6.4*	*13.5*	*15.7*	*11.1*
Other grades	*8.2*	*8.8*	*9.9*	*9.0*	*6.2*	*5.3*	*9.7*	*10.4*

Category/Year	2006	2007	2008	2009	2010	2011	2012
Total production, including:	144.4	153.2	155.9	136.0	124.6	163.6	137.8
Ceramic and glass grades	*121.2*	*130.0*	*136.1*	*124.0*	*112.3*	*150.2*	*122.7*
Ceramic tile grades	*101.5*	*110.0*[e]	*110.0*[e]	*105.0*[e]	*93.0*[e]	*125.0*[e]	*105.0*[e]
Paper grades	*11.8*	*13.1*	*9.7*	*5.4*	*5.0*	*4.8*	*5.3*
Other grades	*11.4*	*10.1*	*10.1*	*6.6*	*7.3*	*7.4*	*9.8*

NA – not available
[e] – estimated
Source: producers’ data

Kaolin raw materials have been produced at the following domestic plants (Tab. 3):

- KSM Surmin-Kaolin of Nowogrodziec: various grades of kaolin manufactured from sandstone with kaolinitic binding from Maria III deposit, as well as from residues after washing of quartz sand from Osiecznica II deposit (30,000–45,000 tpy);
- Grudzeń Las in Sławno near Opoczno: kaolin obtained in course of washing of quartz sand from its own deposits, i.e. Grudzeń Las – at the processing plant Grudzeń Las (since 1993, recently around 70% of the total production), and Piaskownica Zajączków Wschód – at the processing plant in Syski (since 2002, remaining 30% of the total);

Table 3

Kaolin supply structure on the Polish market in 2012

Tabela 3

Struktura podaży kaolinu na rynku polskim w 2012 r.

Voivodship/Country	Supplier	Supply [‘000 t]
Total		**247**
Dolnośląskie/Poland	KSM Surmin-Kaolin	59
Łódzkie/Poland	Grudzeń Las, TKSM Biała Góra	68
Germany	Amberger Kaolinwerke and others	73
Czech Republic	LB Minerals, Sedlecky Kaolin, Kaolin Hlubany	31
United Kingdom	Imerys	7
Ukraine		6
USA		2
France		1

Source: producers’ data, Central Statistical Office (GUS)

- TKSM Biała Góra of Smardzewice: kaolin recovered from residues of quartz sand washing from its own deposits, i.e. Biała Góra I and II Wschód (since 1994), as well as Unewel Zachód (since 2004), until 2001– also Biała Góra III Wesoła;
- until 2001 – Ekoceramika of Nowogrodziec (formerly Ekocer of Bolesławiec): kaolin production based on kaolinite-rich raw materials of various origin, e.g. from Maria III deposit and clayey residue after quartz sand washing from the Osiecznica mine;
- ZPSM Minerał from Wałcz – kaolinite–rich clay (classified as refractory) recovered on a small scale (from 1–2 do 100 tpy) from clayey raw materials from Rusko--Jaroszów deposit.

KSM Surmin-Kaolin of Nowogrodziec (the Lower Silesia) has been the largest and the most specialized domestic supplier of processed kaolin (including ground grades of near 0% moisture as well as bentonite-modified and bleached kaolin). Currently, 100% of the company shares belongs to KiZPPS Osiecznica, while both companies together with former owner of Surmin-Kaolin – Amberger Kaolinwerke Eduard Kick – have been incorporated into Quarzwerke Capital Group. The producer has offered basically ceramic grades (filter cake of 24% moisture, and granulated – 12%, Tab. 4, Lewicka ed. 2012), which in the last two years represented 80–84% of its total supplies (Tab. 2). The remaining 16–20% went to non-ceramic sectors, i.e. the polymer industry (rubber, paints and varnishes, plastics), paper and others. The production of Surmin-Kaolin has constituted from 51 to 55% of the total annual domestic supplies of kaolin.

Kaolin raw materials offered by two other producers, i.e. TKSM Biała Góra and Grudzeń Las, have been primarily consumed in the the ceramic tile industry, and – on a small scale – also in the production of sanitaryware. Increased supplies of this by-product from Grudzeń

Las (37–39% of the total domestic production) should be correlated with growth in sales of sand for the construction materials industry (the major shareholder of the company is Atlas – a leading domestic manufacturer of adhesives and mortars), as well as for the glassmaking industry (e.g. for the needs of Euroglas – modern float glass factory in Ujazd near Łódź, launched in 2009). This raw material is characterized by slightly higher – as compared to standard grades offered by Surmin-Kaolin (Tab. 4) – bending strength after drying and good rheological properties. However, its drawback is relatively high content of colouring oxides (around 2% wt.) and coarse quartz, as well as high commercial humidity (max. 25%).

Until 2000 small quantities of kaolin were recovered at TKSM Biała Góra, ca. 2,000 per year. However, due to rapid growth in demand for this raw material from the domestic ceramic tile industry, the capacity of technological line was expanded up to 30,000 tpy in 2003. This contributed to fast growth of the company's kaolin production, which approached 56,000 tons in 2004 (35% of the domestic supplies). The raw material has been characterized by similar quality parameters as the product of Grudzeń Las. The object of the sale has been also naturally dehydrated material coming from the old settling ponds, which hasn't required any treatment. In recent years the share of TKSM Biała Góra in the domestic kaolin supply has diminished to 10%.

Insufficient supplies of high purity kaolin from national sources, especially of grades complying with requirements of fine ceramics, as well as unfavourable location of some consumers in relation to domestic kaolin production centres, have resulted in its importation. The share of kaolin of foreign origin in the total domestic consumption has maintained at 42–48%, despite the fact that in 2009 the purchases diminished by 28% as compared to the previous year. The main reason of the latter was the reduction of Ukrainian imports from ca. 21,000 tpy in 2007–2008 to some 2,000–5,500 tpy in subsequent years, which was associated with significant increase in the unit values of purchased raw material, from 213 PLN/t in 2008 to 500–600 PLN/t recently (Tab. 5). Its principal recipients have been manufacturers of porcelain goods (especially tableware, electrical porcelain, as well as sanitaryware), paper, and ceramic tiles. In the last five years the majority of washed kaolin deliveries originated from Germany (mainly from Amberger Kaolinwerke) and the Czech Republic (LB Minerals/Lasselsberger, Sedlecky Kaolin and Kaolin Hlubany/WBB). Smaller quantities came from the United Kingdom, France (Imerys), Ukraine and the USA (Tab. 5).

The growth of domestic kaolin consumption, observed since the second half of the 1990s, has been correlated with the recovery in the construction industry and dynamic growth of demand for ceramic goods, especially ceramic tiles (Fig. 1). It was fueled by the so-called construction&renovation tax allowance for individuals and the need for modernization and upgrading of the existing housing infrastructure, as well numerous investments in the public sector (Lewicka 2003). Increased ceramic tile purchases had also proceded the rise in the VAT rate for the construction materials effective from the 1st May, 2004. Its introduction coupled with abolishment of the tax allowance in 2006 resulted in sharp reduction of demand in 2005–2006. The year 2007 brough the demand revival, as Poland was granted the organization of EURO 2012 cup and the related increase of value of infrastructure

Table 4

Quality parameters of selected kaolin grades of domestic and foreign origin

Tabela 4

Parametry jakościowe wybranych krajowych i importowanych surowców kaolinowych

Parameter/Grade	Surmin-Kaolin		Grudzeń Las[1]	Chlumczany[1] (Czech Rep.)	OKA[4] (Germany)	KS-1 S[1] (Ukraine)
	KSP[1, 2]	KOC[1, 3]				
Chemical composition [%]						
SiO_2	71.8	51.5	63.4	50.5	52.0	47.5
Al_2O_3	20.2	34.5	24.8	34.2	34.0	37.3
Fe_2O_3	0.26	0.54	1.41	0.66	0.34	max. 0.50
TiO_2	0.27	0.54	0.62	0.55	0.17	max. 1.20
CaO	0.04	0.08	0.09	0.17	0.18	max. 0.40
MgO	0.04	0.12	0.14	0.20	0.23	0.10
Na_2O	0.01	0.01	0.04	0.12	0.01	0.01
K_2O	0.27	0.63	0.65	2.40	0.26	0.80
LOI	7.10	12.0	8.74	11.2	12.8	13.0
Mineral composition [%]						
kaolinite	54	80	76	73	80	87
illite	5	9	4	–	9	5
quartz	40	9	20	5	11	4
mica	–	–	–	15	–	–
others	1	2	–	2	–	4
Technological parameters						
>45 μm [%]	11.4	0.03	4.5	maks. 0.03	0.05	1.20
viscosity [sec.]	17	12	–	15–30	29	max. 30
drying contraction [%]	1.8	2.5	3.6	4.8	3.0	1.0
firing contraction [%]	1230°C 2.7	1230°C 8.2	1250°C 5.0	–	1410°C 12.5	1250°C 11.0
bending strength [MPa]	0.6	0.7	0.9	1.5	1.9–2.8	1.12
whiteness R 456 [%]	89	80	59	–	90	75

[1] Ceramic tile grade.

[2] Ceramic grade obtained from the clayey raw material from the Osiecznica deposit by filtering and thickening (KSP) and in course of wet classification and magnetic purification (KOS).

[3] Ceramic grade obtained by beneficiation of raw material from Maria III deposit.

[4] For tableware and electroporcelain manufacturing.

Source: KSM Surmin-Kaolin, Grudzeń Las, Lasselsberger, Amberger Kaolinwerke, Euro-Pols

Table 5

Quantity and average unit values of kaolin importation to Poland in 2012, by country

Tabela 5

Kierunki i średnie wartości jednostkowe importu kaolinu do Polski w 2012 r.

Country	Quantity [‘000 t]	Unit value [PLN/t]
Total imports	**120.0**	**431**
Germany	73.2	347
Czech Republic	30.0	371
United Kingdom	7.0	920
Ukraine	5.5	616
USA	1.6	1,618
France	1.4	1,026

Source: Central Statistical Office (GUS)

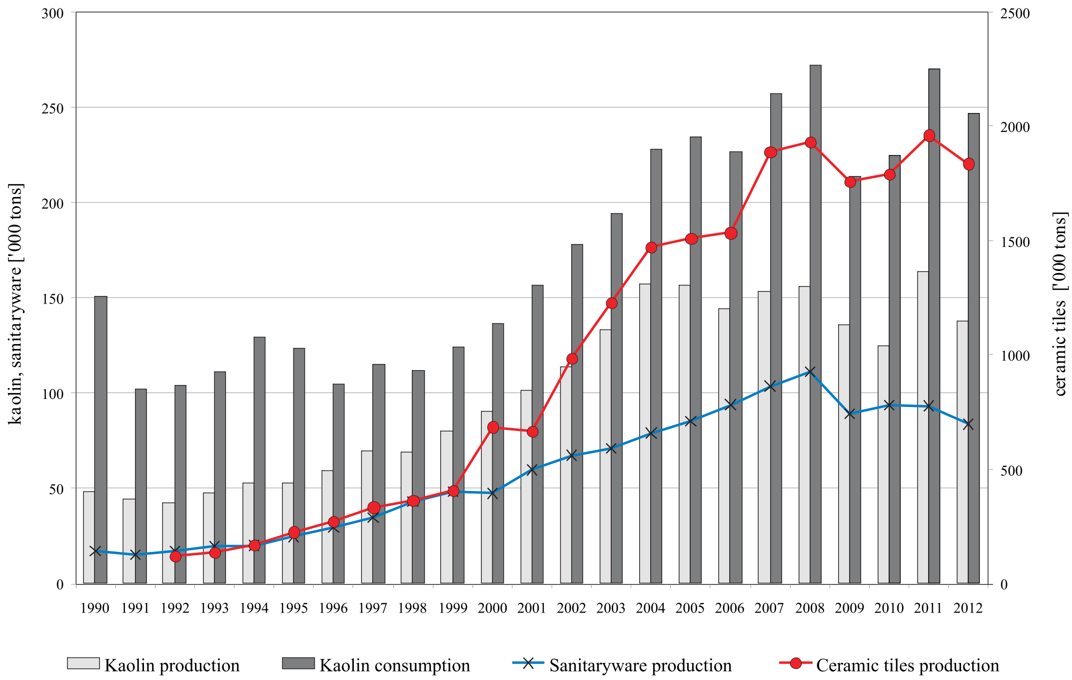

Fig. 1. The production and consumption of kaolin versus the production of ceramic tiles and sanitaryware in Poland, 1990–2012
Source: producers’ data, own calculation, Central Statistical Office (GUS)

Rys. 1. Produkcja i zużycie kaolinu oraz produkcja płytek ceramicznych i wyrobów sanitarnych w Polsce w latach 1990–2012 investments supported by EU funds took place. However, the effect of the latter one was felt only in 2011.

In 2009–2010 the consumption of kaolin in Poland dropped by 18–21% in comparison to its record level in 2008. This was a result of slowdown in the production of ceramics, particularly ceramic tiles and sanitaryware, due to economic downturn and weakened dynamics of the construction industry development (both individual and commercial) in response to the news of the global financial and economic crisis. In view of positive signals coming from domestic market in 2011, the production of kaolin explicitly increased (by 20%), although in 2012 there was a 8.5% reduction owing to economic underperformance of the construction industry.

Since several years the ceramic tile industry has been the driving force behind the development of domestic kaolin market, as well as of other primary raw materials utilized in ceramics, i.e.: white-fireing clays and feldspar-quartz raw materials. The ceramic tile industry has consumed primarily lower-quality kaolin from TKSM Biała Góra and Grudzeń Las (it refers especially to plants located in the Tomaszów-Opoczno region) and the cheapest grades of kaolin from KSM Surmin-Kaolin.

The shares of principal branches in the structure of domestic kaolin consumption is estimated as follows: the ceramic and glass industries – 85–90%, the papermaking – 5–7%, and the polymer industry – 7–8%. Around 80% of kaolin consumed by ceramics alone falls on the manufacturers of ceramic tiles, 10% – sanitaryware, 7% – porcelain tableware, and 2% – eletroporcelain.

The majority of ceramic tile factories is located in the triangle of Tomaszów Mazowiecki (Łódzkie voivodship) – Końskie (Świętokrzyskie voivodship) – and Przysucha (Mazowieckie voivodship). This includes the following manufacturers: Grupa Paradyż, Opoczno I, Ceramika Tubądzin, Cerkolor, Cer-Rol, Ceramika Nowa Gala, and Grupa Końskie. They have consumed kaolin delivered basically by local suppliers (the entire output of TKSM Biała Góra and Grudzeń Las) and – supplementary – from KSM Surmin-Kaolin. Significant amounts of kaolin have been utilized by Lower Silesian ceramic tile manufacturers (Cersanit III, Polcolorit), which have been purchasing raw materials both of domestic (KSM Surmin-Kaolin) and foreign origin (from the Czech Republic and Germany). Relatively small kaolin consumption has been reported by tile producers in the Upper Silesia (Jopex, Ceramika Pilch).

The important consumers of kaolin in the ceramic industry have been producers of fine ceramics, especially of porcelain tableware, although this branch has been experiencing profound and rather irreversible crisis caused by expansion of low-cost Chinese products on the Polish market as well as fluctuations of its profitability dependent on exchange rates (the majority of domestic tableware output has been exported). As a consequence the production of porcelain tableware decreased from 40,000–44,000 tpy in the beginning of the 2000s to around 24,000 tpy in the last couple of years. Manufacturers of porcelain tableware have utilized kaolin of the highest quality imported almost exclusively from Germany, the Czech Republic, and the United Kingdom. The largest domestic consumer of foreign kaolin has been Lubiana (Pomorskie voivodship), relatively smaller – Chodzież (Wielkopolskie voivodship), Ćmielów (Świętokrzystkie voivodship), and Lower Silesian manufacturers.

Significantly smaller consumers of kaolin have been producers of electrical porcelain, i.e.: ZPE Zapel in Boguchwała (Podkarpackie voivodship), Radpol Elektroporcelana in Cieszów and Argillon Polska in Jedlina-Zdrój (both located in the Lower Silesia). The production of electro-porcelain (ranging from 6,000 to 10,000 tpy) requires kaolin of the highest quality, which has been imported from Germany, the Czech Republic and the United Kingdom.

In Poland seven sanitaryware manufacturers have been operating that utilize basically high purity kaolin of foreign origin, i.e. imported from Germany, the Czech Republic and the United Kingdom, as well as the best grades from KSM Surmin-Kaolin. Cersanit I in Krasnystaw (Lubelskie voivodship) and Sanitec Koło in Koło (Wielkopolskie voivodship) have been the largest among them, while the group of relatively smaller ones has included: Roca Polska, Jopex, Ceramika Pilch – all located in Śląskie voivodship, and Hybner of Środa Wielkopolska in Wielkopolskie voivodship. The total production of sanitaryware in Poland increased from below 20,000 tpy in the first half of the 1990s to 85,000–110,000 in the years 2005–2012.

An analysis of past tendencies in demand for kaolin in Poland has indicated that the greatest potential for growth of consumption should be correlated with the ceramic industry development, especially the ceramic tiles sector. This branch, with the production capabilities of 120–140 Mm^2/y of products characterized by the highest quality parameters and modern design, has been able to compete with foreign suppliers on the domestic market and expand sales abroad, especially in Eastern Europe. Indispensable for efficient utilization of domestic production potential in the forthcoming years will be the situation on the investment and construction markets, although much more important role than in previous years will play the development of exportation.

In the case of sanitaryware sector, moderate growth of demand for kaolin is expected in coming years. A a consequence of technological progress, the proportions of raw materials of various origin consumed in that industry have changed to the advantage of imported raw materials. Little hope for the development of domestic kaolin utilization can be linked to the porcelain industry, due to – on one hand – collapse and sharp reduction of the production volume of porcelain tableware, and the fact that the majority of raw materials utilized by this industry has been almost exclusively of foreign origin – on the other hand. The remaining consumers of kaolin in ceramics, i.e. manufacturers of electrical porcelain, white cement and stoneware products, will have little influence on the total kaolin consumption in the future.

An opportunity of possible growth in demand for kaolin could be created by the technology of hydraulic fracturing which utilizes ceramic materials as proppants in exploitation of shale gas. Ceramic proppants, due to greater uniformibility of paricle size, improved shape (sphericity) and higher mechanical strength in comparison to sand which is definitely cheaper and therefore more frequently used so far, contribute to even two-fold increase of the drill-hole efficiency. Assuming the expansion of shale gas extraction in Poland and also abroad (Ukraine, Russia), that application of kaolin can not be entirely ruled out, the more that in the second half of 2015 a new, modern plant for light and ultralight ceramic proppants manufacturing is expected to run by the Baltic Ceramics in Lubsko (Lubuskie voivodship). The production will be based on local source of refractory clays. It will be the first such a plant in Europe, of initial production capacity around 60,000 tpy (in subsequent phases of start-up possible expansion to 135,000 and even to 180,000 tpy by 2020).

Kaolin deposits in Poland occur quite abundantly. At the end of 2012 total resources of 14 deposits amounted to 212.9 Mt, including 79.8 Mt (72.2 Mt of economic resources) in operated deposits. Assuming that total current demand of ca. 250,000 tpy will be met from domestic sources, the resources sufficiency is evaluated at around 290 years. This means that in the long term kaolin supplies to the largest domestic consumers of the raw material – ceramic tile producers, are guaranteed. An important area of potential kaolin resources (19.9 Mt) has remained Antoni (Kalno) deposit in Świdnica region (Bilans perspektywicznych… 2011), which is recognised sufficiently to start its extraction in the future.

Taking into account the geographic location of the largest producers of ceramic tiles, such as: Opoczno, Końskie Group, Ceramika Paradyż, Ceramika Tubądzin, Ceramika Nowa Gala, which form a kind of „tile basin" in central Poland, and location of Cersanit and Polcolorit in the Lower Silesia, it can be concluded that they are logistically perfect from the point of view of domestic kaolin suppliers. Some manufacturers whose factories are located at larger distance from domestic sources of kaolin, have imported it from abroad, basically from the Czech Republic and Germany, which has been determined primarily by transportation costs. The distribution of sanitaryware plants in Poland is rather dispersed in comparison to the ceramic tile sector. Factories of the largest producers are located in the north (Sanitec Koło in Koło and Włocławek) and east of the country (Cersanit in Krasnystaw), while the majority of raw materials for their production has been imported, which has been determined not only by logistic issues but also by kaolin quality. Such producers as Hybner in Środa Wielkopolska or Ceramika Pilch in Jasienica near Bielsko Biała have had the opportunity to diversify their purchases (presumably a part of supplies has come from the Czech Republic and Germany).

Assuming very probable growth in demand for kaolin associated with expected overcoming the temporary crisis in the construction industry and finalizing of ongoing investments, the prospects for utilization of domestic suppliers' capacities look optimistic. The vast potential of kaolin supply development is associated with the use of waste material generated in course of quartz sand washing and accumulated in settling ponds of Grudzeń Las and TKSM Biała Góra. Also Surmin-Kaolin – a leading national kaolin supplier – has a capability to increase the production up to 100,000 tpy. Therefore, in perspective of 2020 the total kaolin supply from indigenous sources could exceed 200,000 tpy, which would entirely satisfy possible increase of domestic demand for lower grades of kaolin (not destined for tableware porcelain and porcelain sanitaryware, which still will have to be imported). In an optimistic scenario, which assumes further growth of the ceramic goods production, especially ceramic tiles and ceramic proppants, the consumption of kaolin both of domestic and foreign origin in Poland could approach 350,000 tpy.

1.2. Ceramic clays (white-firing, stoneware, refractory)

Ceramic clays sourced from various deposits are characterized by considerable diversity of mineral composition and quality parameters. Therefore, they could be utilized in various applications in the ceramic industry, including the production of ceramic tiles, sanitaryware, semi-vitreous chinaware and stoneware, as well as alumino-silicate (chamotte) refractories. In Poland, owing to confirmed technological suitability of these raw materials, they have been divided into three basic groups, i.e.:

- white-firing clays (called also: kaolinitic clays, ball clays, or faience clays) – the noblest varieties of ceramic clays, utilized in the production of white-body ceramic goods, including faience and porcelain tiles, semi-vitreous chinaware or sanitaryware, and even porcelain; their key parameters include: content of colouring oxides (Fe_2O_3 + TiO_2) below 2.5%, whiteness after firing at 1,200°C above 60%, bending strength – min. 1.5 MPa;
- refractory clays – kaolinite clays suitable for the production of chamotte refractories, and – to an increasing extent – also for manufacturing of some types of ceramic tiles or sanitaryware; their principal features include: refractoriness in the range of 1,650–1,750°C and Al_2O_3 content between 23 and 39% (depending on variety);
- stoneware clays – clayey raw materials of very good sinterability, applicable in the production of coloured-body ceramic tiles, sewage pipes, sanitary products, acid-resistant and clinker goods; they are characterized by low water absorption after firing (<4% at 1,300°C), bending strength after drying – min. 2 MPa (plastic varieties) and even >3 MPa (very plastic varieties).

The above-mentioned classification should be applied flexibly, as clays from each group could be utilized in other applications than specified (Bilans gospodarki... 2014; Wyszomirski and Galos 2007).

The resources of ceramic clays in Poland are very diverse. White-firing clays form lenses and irregular seams in Cretaceous formations near Bolesławiec in the Lower Silesia. Total resources of six deposits in this region amounted to 59.1 Mt (Mineral Resources Datafile... 2013). Clays of that type accompany also stoneware and refractory clays in operated deposits of lignite (Turów, Bełchatów), but their resources have not been documented. White-firing clays have been also sourced from sandy-clayey sediments documented as foundry sand.

Refractory clay deposits are located and extracted in the Lower Silesia (in the vicinty of Strzegom, Bolesławiec, Żary and Turoszów), and in north-eastern margin of the Świętokrzyskie Mts. At the end of 2012 their total anticipated economic resources were 54.7 Mt, including 43.7 Mt in deposits of Jaroszów region (Mineral Resources Datafile... 2013). The deposits occurring in this region, e.g. Rusko-Jaroszów (the only one currently operated), are of the largest importance in the country, both in terms of documented resources and prospects for their development. The prognostic resources of this area are estimated at around 57 Mt (Bilans perspektywicznych... 2011). Nevertheless, economic resources of Rusko-Jaroszów deposit have been only ca. 1.5 Mt and can be exhausted within 10–15 years, while the development of documented and prognostic deposits can be difficult due to environmental and spatial issues. Deposits of refractory clays in other locations – near Żary in the Lower Silesia and in the Opoczno-Przysucha area in northern margin of the Świętokrzyskie Mts. – contain clays of lower grades and are not currently extracted.

The resources of stoneware clays in Poland are abundant. Their deposits are located in northern margin of the Świętokrzyskie Mts. (Triassic clays of Suchedniów region and Jurassic clays in Opoczno-Przysucha area) as well as in the Lower Silesia (Cretaceous and Tertiary clays in vicinity of Bolesławiec, Gozdnica and Wrocław). Stoneware clays occur as an accompanying raw materials in operated deposits of lignite, Turów and Bełchatów. At the end of 2012 total resources of stoneware clays amounted to 77.1 Mt (Mineral Resources Datafile... 2013). Minerals of similar properties, derived from deposits of clays for building ceramics, especially in the Opoczno-Przysucha area, Lubliniec in the Upper Silesia, Bolesławiec and Żary in the Lower Silesia, have been also utilized in manufacturing of stoneware goods.

The production of white-firing clays was always limited to Bolesławiec vicinity, where they were mined for ages (Lewicka and Galos 2004). After the Second World War they were extracted by underground method from the following deposits: Maria I (until 1960), Anna (by 1970), Janina (by 1980), Bolko (by 1990), and Bolko II (by 1997). Simultaneously, variable amounts of these clays have been intermittently mined from the so-called B layer interbedding lignite in Turów mine (Tab. 6). Since 2003 the major producer of white-firing clays in Poland has been Ekoceramika, operating Janina I deposit and adjacent beneficiation plant in Suszki near Bolesławiec, where the sandy-clayey run-off-mine has been processed into washed white-firing clay (Tab. 6). Recently this production has ranged from 30,000 to 50,000 tpy, with a reduction in 2012. Since 2006, white-firing clays have been also manufactured by Bolesławieckie Refractories Plant at processing plant in Czerwona Woda near Węgliniec. In recent years their output has not exceeded 10,000 tpy (Bilans gospodarki... 2014). White-firing Turoszów clays, which have been periodically extracted from B layer of Turów deposit and collected in the landfill, have been sold in various quantities or – in a small quantity – processed at KSM Surmin-Kaolin of Nowogrodziec together with other kaolin semi-products derived from Maria III deposit into white-firing granulate (Tab. 7). Their recent production has ranged from 2,000 to 4,000 tpy. In the 1990s the total output of white-firing clays in Poland was hardly approaching 20,000 tpy, while in subsequent years it remained at much higher level – usually 30,000–55,000 tpy up to almost 70,000 t in 2010. In 2012 it was reduced to 35,000 tons (Tab. 8).

Refractory clays have been utilized on an industrial scale in the Polish territories for over 150 years. For decades they were sourced from Jaroszów, Opoczno, Żary, Bolesławiec regions, and since the 1980s – also from Turów lignite mine (Lewicka and Galos 2004). By 1989 their total mining output exceeded 1 Mtpy, but between 1990 and 1993 it was reduced from almost 500,000 to below 300,000 tpy (Tab. 6). In subsequent years it was showing a general downward trend, especially in 2008–2012, when it ranged from 70,000 to 110,000 tpy. The most important domestic supplier of refractory clays has been JARO of

Table 6

Mining output of ceramic clays in Poland [‘000 t]

Tabela 6

Wydobycie iłów ceramicznych w Polsce [tys. t]

Clay/Mine/Year	1990	1991	1992	1993	1994	1995	1996	1997
White-firing clays								
Total output	**7**	**135**	**4**	**7**	**4**	**5**	**8**	**5**
Bolko/ Bolko II	7	7	4	7	4	5	4	2
Janina I	–	–	–	–	–	–	–	
KWB Turów	–	129	–	–	–	–	4	3
Refractory clays								
Total output	**482**	**420**	**334**	**292**	**350**	**261**	**250**	**231**
Chwaliszowice	0	11	13	0	3	3	2	3
Łęknica II/III	27	19	19	–	26	–	–	–
Rusko-Jaroszów	427	365	272	255	275	238	212	177
Kryzmanówka (Zapniów)	28	25	21	18	22	20	21	26
KWB Turów	–	–	9	19	24	0	15	25
Stoneware clays								
Total output	**241**	**170**	**204**	**146**	**177**	**159**	**122**	**102**
Baranów	69	66	50	43	32	29	25	20
Gozdnica / Gozdnica II	46	4	59	0	36	21	0	5
Kraniec	13	9	14	19	27	16	24	26
KWB Turów	46	33	17	15	9	0	15	0
Paszkowice (Żarnów II)	25	32	31	31	33	34	24	24
Zebrzydowa	42	26	33	38	40	31	34	27
Zebrzydowa Zachód	–	–	–	–	–	–	–	–
Clays for building ceramics with properties of stoneware clays [‘000 m^3][1]								
Total output	**183**	**149**	**170**	**171**	**271**	**NA**	**239**	**173**
Chełsty	–	–	–	23	36	NA	33	13
Gozdnica / Gozdnica II	78	80	93	73	134	NA	114	77
Jasień I / Jasień II	2	2	–	0	3	NA	0	0
Kozów	–	–	–	–	–	NA	–	–
Lipie Śląskie	5	5	4	5	4	NA	6	6
Mirostowice Dolne S		0	–	–	–	NA	27	38
Ołdrzychów		12	14	6	3	NA	2	2
Pałęgi	–	–	–	–	–	NA	–	–
Patoka	29	27	36	44	68	NA	40	20
Słowiany	49	18	20	17	15	NA	15	13
Szkucin	–	–	–	–	–	NA	–	–
Woźniki Śląskie	16	2	3	0	2	NA	1	1
Zelczów Południowy	–	–	–	–	–	NA	1	1
Żagań	4	3	0	3	6	NA	0	2

Table 6 cont.

Tabela 6 cd.

Clay/Mine/Year	1998	1999	2000	2001	2002	2003	2004	2005
White-firing clays								
Total output	**0**	**13**	**9**	**10**	**1**	**–**	**–**	**33**
Bolko/ Bolko II	–	–	–	–	–	–	–	–
Janina I	–	–	9	10	1	–	–	33
KWB Turów	0	13	–	–	–	–	–	–
Refractory clays								
Total output	**197**	**151**	**166**	**151**	**130**	**149**	**150**	**152**
Chwaliszowice	2	–	–	–	–	–	–	–
Łęknica II/III	–	–	–	–	–	–	–	–
Rusko-Jaroszów	150	115	127	107	100	119	122	129
Kryzmanówka (Zapniów)	31	22	25	34	24	30	28	23
KWB Turów	14	14	14	12	6	–	–	–
Stoneware clays								
Total output	**220**	**167**	**214**	**172**	**133**	**127**	**242**	**199**
Baranów	30	17	33	33	9	7	29	26
Gozdnica / Gozdnica II	81	42	72	44	30	2	24	27
Kraniec	35	37	31	15	8	9	11	14
KWB Turów	17	10	11	10	6	–	–	–
Paszkowice (Żarnów II)	33	41	41	36	32	38	44	42
Zebrzydowa	23	21	26	34	48	71	134	90
Zebrzydowa Zachód	–	–	–	–	–	–	–	–
Clays for building ceramics with properties of stoneware clays [‘000 m^3][1]								
Total output	**118**	**131**	**131**	**166**	**208**	**229**	**229**	**202**
Chełsty	16	19	28	30	30	28	23	16
Gozdnica / Gozdnica II	21	33	43	41	27	44	54	31
Jasień I / Jasień II	–	–	–	0	16	11	8	11
Kozów	–	–	–	–	–	–	9	63
Lipie Śląskie	6	6	–	–	–	–	–	–
Mirostowice Dolne S	25	21	–	–	–	–	–	–
Ołdrzychów	3	1	1	2	1	1	1	1
Pałęgi	–	–	–	31	60	45	46	20
Patoka	25	31	49	55	51	66	73	71
Słowiany	15	15	10	4	6	8	8	4
Szkucin	–	–	–	2	2	4	6	9
Woźniki Śląskie	3	1	–	1	1	1	–	–
Zelczów Południowy	0	0	–	–	–	–	1	–
Żagań	4	4	–	–	–	–	–	–

Table 6 cont.

Tabela 6 cd.

Clay/Mine/Year	2006	2007	2008	2009	2010	2011	2012
White-firing clays							
Total output	**98**	**127**	**122**	**142**	**160**	**131**	**94**
Bolko/ Bolko II	–	–	–	–	–	–	–
Janina I	98	127	122	142	160	131	94
KWB Turów	–	–	–	–	–	–	–
Refractory clays							
Total output	**180**	**170**	**149**	**98**	**71**	**109**	**92**
Chwaliszowice	–	–	–	–	–	–	–
Łęknica II/III	–	–	–	–	–	–	–
Rusko-Jaroszów	164	150	126	98	71	109	92
Kryzmanówka (Zapniów)	16	20	23	–	–	–	–
KWB Turów							
Total output	**148**	**141**	**225**	**162**	**185**	**215**	**177**
Baranów	4	9	14	11	18	24	13
Gozdnica / Gozdnica II	–	–	–	–	–	–	–
Kraniec	15	17	24	–	–	–	–
KWB Turów	–	–	–	–	–	–	–
Paszkowice (Żarnów II)	32	32	28	26	24	14	–
Zebrzydowa	97	13	–	–	–	–	–
Zebrzydowa Zachód	–	90	159	125	143	177	164
Clays for building ceramics with properties of stoneware clays [‘000 m^3][1]							
Total output	**286**	**202**	**288**	**212**	**194**	**179**	**175**
Chełsty	20	28	32	29	24	33	31
Gozdnica / Gozdnica II	29	45	49	49	28	3	17
Jasień I / Jasień II	13	14	8	12	6	–	–
Kozów	29	25	25	19	21	24	22
Lipie Śląskie	–	2	1	–	1	1	5
Mirostowice Dolne S	–	45	–	25	–	–	–
Ołdrzychów	1	1	1	0	1	–	–
Pałęgi	31	36	73	2	47	44	61
Patoka	65	64	70	61	45	54	24
Słowiany	5	9	9	–	2	–	–
pnumSzkucin	8	16	19	14	18	19	15
Woźniki Śląskie	1	1	1	1	1	1	0
Zelczów Południowy	–	–	–	–	–	–	–
Żagań	–	–	–	–	–	–	–

[1] Utilized in large part for the production of stoneware goods (mainly ceramic tiles).

NA – not available.

Source: Mineral Resources Datafile

Jaroszów, extracting Rusko-Jaroszów deposit. For many years its production accounted for 85–90% of the consumption of refractory clays in Poland, while since 2009 JARO has become the sole domestic manufacturer, supplying the highest grades of these clays, which represented 55–65% of the total company's output (Tab. 9, Bilans gospodarki... 2014). In the 1980s the production of refractory clays in Jaroszów exceeded 600,000 tpy (Galos 1999). Owing to reduced demand from the refractory industry, this supplies gradually decreased to 100,000–120,000 tpy after 2000 and 70,000–100,000 tpy in the recent years

Table 7

Basic quality parameters of domestic white-firing and light-firing clays

Tabela 7

Podstawowe parametry jakościowe krajowych iłów biało i jasno wypalających się

Parameter	Ekoceramika Janina JB1W	Surmin-Kaolin TC1/WB	BZMO CWW	Ekoceramika Zebrzydowa
Chemical composition [wt. %]				
SiO_2	58.2	56.4	67.0	62.0
Al_2O_3	29.3	29.9	21.0	23.0
Fe_2O_3	0.61	0.74	1.20	2.19
TiO_2	0.65	0.81	0.95	1.41
CaO	0.06	0.08	0.38	0.20
MgO	0.40	0.20	0.25	0.50
K_2O	1.14	0.81	1.20	1.27
Na_2O	0.01	0.06	0.08	0.04
LOI	9.7	10.7	7.4	7.5
Mineral composition [%]				
Kaolinite	60	65	36	35
Illite	20	13	21	29
Quartz	19	20	40	34
Others	1	2	<3	2
Fraction >63 µm [%]	2–6	3.9	8.5	<17
Technological properties				
Bending strength [MPa]	3.0	2.0	2.9	3.6
Drying shrinkage [%]	3–5	2.5	3.3	4.0
Firing shrinkage [%]	5–9 (1250°C)	7.3 (1230°C)	6.6 (1230°C)	8.0 (1200°C)
Water absorption after firing [%]	6–10 (1250°C)	8.0 (1230°C)	7.4 (1230°C)	12.0 (1200°C)
Whiteness [%] or colour after firing	light creamy	77 (1230°C)	68 (1230°C)	light grey

Source: Galos and Wyszomirski 2006

(Tabs. 6, 8). Refractory clays of lower grades were also mined in other regions of Poland, including Opoczno (by 1990), Żary (by 1998), and in Turów (until the end of the 1990s). The exception was Zapniów mine near Przysucha, where refractory clay was extracted by 2009. For several years the output of that mine varied between 20,000 and 30,000 tpy. However, due to depletion of the deposit resources, it was terminated in 2009 (Tab. 6).

Table 8

Ceramic clays statistics in Poland [‘000 t]

Tabela 8

Gospodarka iłami ceramicznymi w Polsce [tys. t]

Clay/Year	1990	1991	1992	1993	1994	1995	1996	1997
Production								
White-firing clays	NA	NA	0.0	2.4	14.5	15.4	16.9	20.4
Stoneware clays*	NA	NA	NA	NA	33.0	25.0	30.0	23.0
Refractory clays, raw	523.0	443.0	362.0	316.0	319.0	275.0	248.0	198.5
Exports								
White-firing clays	NA	NA	NA	NA	NA	NA	10.4	4.6
Stoneware clays	NA	NA	0.1	0.1	0.3	3.3	9.7	11.9
Refractory clays, raw	13.9	8.8	4.1	5.3	5.6	7.3	36.3	56.2
Imports								
White-firing clays	NA	NA	NA	NA	NA	NA	17.5	14.3
Stoneware clays	NA	NA	3.0	3.1	5.0	3.8	7.0	21.4
Refractory clays, raw	3.8	0.2	2.0	5.3	3.3	1.3	6.3	10.3

Clay/Year	1998	1999	2000	2001	2002	2003	2004	2005
Production								
White-firing clays	17.7	13.9	16.5	25.9	30.1	32.9	31.1	36.0
Stoneware clays*	18.3	17.8	575.7	435.9	265.1	335.8	567.5	528.6
Refractory clays, raw	174.6	140.4	152.8	139.6	127.9	143.9	136.8	155.8
Exports								
White-firing clays	0.0	0.1	0.1	0.0	0.1	0.3	–	0.1
Stoneware clays	1.2	2.1	1.5	2.9	1.8	4.0	3.5	3.2
Refractory clays, raw	58.0	50.7	11.6	18.7	14.0	6.1	12.4	11.6
Imports								
White-firing clays	11.4	7.5	4.6	5.4	6.9	9.4	8.9	9.4
Stoneware clays	28.6	45.2	25.4	49.7	58.8	66.4	87.7	89.9
Refractory clays, raw	6.4	24.9	88.1	187.5	203.7	272.1	252.8	339.7

Table 8 cont.

Tabela 8 cd.

Clay/Year	2006	2007	2008	2009	2010	2011	2012
Production							
White-firing clays	38.2	56.7	55.7	41.7	69.8	48.4	35.0
Stoneware clays*	738.3	980.1	906.4	646.2	721.1	1,291.6	736.5
Refractory clays, raw	186.6	198.0	169.2	114.7	81.7	136.4	118.9
Exports							
White-firing clays	0.1	0.1	0.1	0.0	1.1	1.2	0.7
Stoneware clays	0.4	0.1	2.0	12.0	14.9	13.7	11.8
Refractory clays, raw	19.0	22.4	16.2	11.7	14.2	13.9	9.9
Imports							
White-firing clays	10.7	14.0	13.1	9.4	13.4	9.2	15.7
Stoneware clays	85.5	82.2	103.5	71.5	77.4	125.0	133.5
Refractory clays, raw	208.7	317.1	313.9	212.6	248.2	313.6	259.5

* Since 2000 sold production of common clays (stoneware clays and building ceramics clays) reported by GUS.

NA – not available.

Source: Central Statistical Office (GUS)

A part of obtained Jaroszów refractory clays has been thermally processed in rotary kilns on site into burnt refractory clays, which have been also utilized in the refractory industry. Their production, exceeding 200,000 tpy in the 1980s, was gradually decreasing to less than 30,000 in 1995, while in subsequent several years it ranged from 25,000 to 50,000 tpy, with substantial reduction in the years 2009–2012 (Tab. 10).

Stoneware clays were mined and utilized in Poland for centuries. Centres of their production were formed in the nineteenth century in the Lower Silesia and the Świętokrzyskie Mts. Also nowadays they have been mined in the northern margin of the Świętokrzyskie Mts. (Triassic clays in Suchedniów region and Jurassic clays in Opoczno and Przysucha vicinity) as well as in the Lower Silesia, near Bolesławiec (Cretaceous and Tertiary clays) and Żary (Tertiary clays). Mining output from deposits documented as stoneware clays has ranged from 100,000 to 240,000 tpy, with significant fluctuations in the number of active mines (Lewicka and Galos 2004). The only deposit that has been operated uninterruptedly has been Baranów one near Suchedniów. In 2007 in place of Zebrzydowa mine near Bolesławiec a new Zebrzydowa Zachód mine was launched, whereas the extraction of stoneware clays from several deposits was abandoned (Tab. 6). For the production of a wide variety of stoneware and clinker goods there have been increasingly

Table 9

Basic quality parameters of Jaroszów refractory clays

Tabela 9

Podstawowe parametry jakościowe jaroszowskich iłów ogniotrwałych

Parameter	G1 (G1/C)	G2 (G2/C)	G3 (G3/C)	G4
Chemical composition [wt. %]				
SiO_2	54–56	56–58	59–63	64–70
Al_2O_3	37–39	35–37	29–35	23–29
TiO_2	<1.0	<1.4	<1.7	<2.2
Fe_2O_3	2.2–2.7 (1.8–2.5)	2.4–2.8 (1.8–2.5)	2.2–3.0 (1.8–2.5)	<2.5
CaO	<0.4	<0.5	<0.5	<0.6
MgO	<0.6	<0.6	<0.6	<0.6
$Na_2O + K_2O$	1.5–2.1	1.6–2.2	1.6–2.2	1.2–1.8
LOI	11–14	12–14	9–14	9–14
Mineral composition [%]				
Kaolinite	>72	>70	>70	>58
Illite	<23	<24	<24	<24
Quartz	<3	<4	<13	<31
Melting point [°C]	1,750	1,730	1,690	1,650
Fraction >63 µm [%]	<2	<3	<8	<8

Source: producer's data

utilized clays from deposits formally documented as clays for building ceramics. These clays are often characterized by very similar or even analogous properties as mineral raw material from stoneware clays deposits; therefore they have been utilized to a large extent for these purposes. These include mainly: Triassic red clays from the northern margin of the Świętokrzyskie Mts. as well as Miocene-Pliocene clays from Żary in the Lower Silesia (Bilans gospodarki... 2014). In recent years the total mining output of these clays has been generally increasing, approaching 290,000 m^3 (over 570,000 tons) in 2008, with a sharp reduction to 175,000 m^3 in 2012 (Tab. 11). Since 2000 no official data on the domestic production of stoneware clays has been available. The Central Statistical Office (GUS) has included their production in more general item of PKWiU classification – 08122250 'Common clays and shales for building ceramics' – together with other clays, e.g. for building ceramics. The latter ones, however, have been almost entirely utilized in ceramic plants of companies exploiting these clays, and have been sold to other recipients very

Table 10

Burnt refractory clays statistics in Poland [‘000 t]

Tabela 10

Gospodarka iłami ogniotrwałymi palonymi w Polsce [tys. t]

Item/Year	1990	1991	1992	1993	1994	1995	1996	1997
Production	120.2	99.2	75.8	66.3	69.7	72.8	61.4	56.1
Exports	2.4	5.9	0.0	0.1	–	1.5	6.2	6.2
Imports	0.1	0.1	0.4	1.0	0.6	3.4	2.5	4.4
Apparent consumption	117.9	93.4	76.2	67.2	70.3	76.2	62.4	54.3

Item/Year	1998	1999	2000	2001	2002	2003	2004	2005
Production	45.7	36.0	37.7	32.8	26.8	36.4	31.7	41.7
Exports	0.1	0.1	0.1	0.3	0.2	3.3	0.1	0.3
Imports	7.7	10.7	12.2	4.3	4.5	6.0	8.1	0.3
Apparent consumption	53.5	46.6	49.8	36.8	31.1	39.1	39.7	47.0

Item/Year	2006	2007	2008	2009	2010	2011	2012
Production	53.2	54.3	49.4	35.0	25.2	37.7	30.6
Exports	0.4	0.1	0.1	0.2	0.3	0.4	0.5
Imports	0.4	0.1	0.1	0.2	0.3	0.4	0.5
Apparent consumption	58.1	59.4	55.9	38.8	32.2	43.8	39.1

Source: Central Statistical Office (GUS)

seldom. A situation has been different in the case of stoneware clays, which have been largely traded between their manufacturers and customers. Therefore, the data on the volume of marketed clays collected in PKWiU 08122250 at least approximately reflect the volume of the domestic production of stoneware clays and related raw materials. In recent years it has varied from 720,000 to 1,290,000 tpy (Tab. 12).

Demand of the domestic ceramic industry for ceramic clays has not been fully covered by Polish suppliers. The subject of international turnover has been mainly white-firing clays and high quality refractory clays. Stoneware clays have been traded in a marginal way owing to the abundance of their deposits in the country. The trade of refractory clays is registered within CN code 2508 30, while that of white-firing clays should be recorded within CN code 2507 00 80 (kaolin clays), though only a small part of them has been actually reported here, while their importation from Ukraine has been included in CN code 2508 30 (refractory clays), whereas deliveries from Germany and – in a part – from the Czech Republic – in CN

2508 40 (stoneware clays and others). Since the mid-1990s strong growth in ceramic clays importation to Poland has been reported (Tabs. 11, 12), which has has been a consequence of rising demand mainly from ceramic tiles and sanitaryware producers for white- and light-firing clays (Lewicka and Galos 2004). This has been partly attended by manufacturers of refractories, purchasing cheaper refractory clays of foreign origin (mainly Ukrainian). In 2008 total imports of ceramic clays to Poland exceeded 430,000 tons, and after explicit decrease in the following two years, was restored to a record 447,800 tons in 2011, with a slight reduction in 2012 (Tab. 11). It is estimated that over 90% of its volume have been imported by producers of ceramic tiles and sanitaryware, while around 10% (30,000––40,000 tpy) – by manufacturers of refractories. Over the last couple of years ceramic clays have been delivered to Poland basically from Ukraine and Germany (93–95% of the total imports), with smaller quantities coming from the United Kingdom, the Czech Republic, the United States, and occasionally – also from Italy, Spain, Portugal, and others (Tabs. 11, 12). Ukrainian clays has originated mainly from Donieck region, in particular from two companies: Vesco and Donbas Clays, while German ones – almost exclusively from Meisen--Lusatian plants of Stephan Schmidt Meißen and Kaolin und Tonwerke Seilitz-Löthain. The main suppliers of clays from the United Kingdom have been WBB Minerals and Imerys, while from the Czech Republic – LB Minerals (Bilans gospodarki... 2014). Imports of burnt clays, coming from Ukraine, the Czech Republic, the USA, France, and Germany, in recent years have ranged between 4,000 and 8,000 tpy (Tab. 10).

Some varying amounts of ceramic clays have been also regularly exported (Tab. 8). The majority has been raw refractory clays from Rusko-Jaroszów deposit, annual sales of which haven't exceeded several thousand tons. Their main customers have been the Czech Republic, Germany, Hungary, Macedonia and Switzerland. Some negligible exportation of burnt refractory clays has been also recorded (Tab. 10).

In recent years average unit values of importation of raw refractory clays and white--firing clays recorded within CN code 2508 30 have systematically increasing, from around 100 PLN/t in 2004 to over 300 PLN/t in 2012, largely as a result of significant growth in prices of previously cheap Ukrainian clays. Unit costs of importation of clays registered as their stoneware variety in CN code 2508 40, coming almost exclusively from Saxony, have ranged predominantly between 240 and 260 PLN/t, with considerable reduction to 230 USD/t in 2012, while these values for imported kaolin clays (CN 2507 00 80), brought mainly from the United Kingdom – have been several times higher (Tab. 13).

Ceramic clays, together with kaolin, feldspar and quartz, are the basic raw materials for the production of numerous ceramic articles, including: ceramic tiles of faience, porcelain, stoneware and clinker varietes, sanitaryware ceramics (basically from porcelain and earthenware), semi-vitreous china-ware (mainly dishes and fancy goods), stoneware goods other than tiles (acid-resistant, electrotechnical, pottery, sewerage pipes), as well as refractory shaped chamotte products and refractory mortars and masses (Fig. 2).

Table 11

Imports of ceramic clays to Poland, by country [‘000 t]

Tabela 11

Kierunki importu iłów ceramicznych do Polski [tys. t]

Clay/Country/Year	1996	1997	1998	1999	2000	2001	2002	2003	2004
Ceramic clays	**30.8**	**46.0**	**46.4**	**77.6**	**118.1**	**242.6**	**269.4**	**347.9**	**349.4**
China	–	–	0.1	–	0.0	0.0	0.0	0.1	0.1
Czech Republic	12.4	10.5	6.0	5.7	2.0	1.7	2.6	1.8	3.2
Germany	8.5	12.6	14.8	20.8	22.2	48.3	58.3	66.4	87.1
Italy	0.0	0.0	0.0	0.0	–	0.2	0.1	0.3	0.1
Portugal	–	–	–	–	–	–	–	–	0.2
Spain	–	–	0.5	0.0	0.1	0.2	0.1	0.1	–
Ukraine	3.3	21.3	21.8	46.1	88.7	186.2	201.6	270.0	250.4
United Kingdom	1.9	2.1	1.6	3.2	4.4	5.6	5.8	6.0	6.7
USA	4.0	0.0	0.7	0.0	0.0	0.0	0.1	3.0	1.5
Others	0.7	0.7	1.0	1.8	0.8	0.4	0.8	0.3	0.1
White-firing clays	**17.5**	**14.3**	**11.4**	**7.5**	**4.6**	**5.4**	**6.9**	**9.4**	**8.9**
Czech Republic	11.4	5.2	2.7	0.9	0.3	0.4	0.3	0.2	0.5
Germany	3.7	4.4	3.7	4.2	2.5	1.9	0.4	0.5	0.4
Ukraine	0.1	2.1	1.9	0.2	0.0	0.4	0.0	0.0	0.0
United Kingdom	1.9	2.1	1.6	1.7	1.4	2.3	5.8	5.5	6.3
USA	0.0	0.0	0.7	0.0	0.0	0.0	0.1	2.9	1.4
Others	0.4	0.5	0.8	0.5	0.3	0.4	0.4	0.3	0.3
Refractory clays	**6.3**	**10.3**	**6.3**	**24.9**	**88.1**	**187.5**	**203.7**	**272.1**	**252.8**
China	–	–	0.1	–	–	–	–	–	–
Czech Republic	–	1.3	0.1	0.9	0.6	1.0	2.2	0.9	1.4
France	0.1	0.1	0.0	–	–	–	–	–	–
Germany	0.2	1.4	0.2	0.2	0.5	0.8	0.6	0.7	0.9
Ukraine[1]	2.0	8.8	5.8	23.8	86.9	185.6	200.8	269.9	250.2
United Kingdom	–	–	0.0	–	0.0	0.0	0.0	0.5	0.3
USA	4.0	0.0	0.0	–	–	–	–	–	–
Stoneware and other clays	**7.0**	**21.4**	**28.7**	**45.2**	**25.4**	**49.7**	**58.8**	**66.4**	**87.7**
Czech Republic	1.0	4.0	3.2	3.9	1.1	0.3	0.2	0.6	1.3
Germany	4.6	6.8	11.1	16.4	19.2	45.6	57.3	65.2	85.8
Italy	0.0	0.0	0.0	0.0	–	–	0.1	0.2	0.1
Spain	–	–	0.5	0.0	0.1	0.1	0.1	–	0.2
Ukraine	1.2	10.4	14.1	22.1	1.7	0.2	0.8	0.1	0.2
United Kingdom	–	–	–	1.5	3.0	3.3	0.0	0.0	0.1
Others	0.2	0.2	0.2	1.3	0.2	0.2	0.4	0.2	0.1

Table 11 cont.

Tabela 11 cd.

Clay/Country/Year	2005	2006	2007	2008	2009	2010	2011	2012
Ceramic clays	**439.0**	**376.9**	**413.3**	**430.5**	**293.5**	**339.0**	**447.8**	**408.8**
China	0.0	0.5	0.0	0.8	–	–	0.6	0.4
Czech Republic	4.3	6.4	5.3	5.8	7.4	11.4	22.2	18.4
Germany	85.4	78.9	76.7	103.0	64.0	66.2	111.8	132.6
Italy	3.5	0.1	0.1	0.2	0.1	0.0	0.0	0.0
Portugal	0.1	0.2	1.0	1.5	1.7	1.6	2.1	2.5
Spain	–	–	–	–	3.6	0.2	–	–
Ukraine	337.9	281.7	317.1	306.9	209.2	250.4	206.4	251.1
United Kingdom	7.5	8.5	8.3	7.3	5.2	8.3	3.5	3.1
USA	0.1	0.1	3.2	3.7	1.8	0.4	0.4	0.5
Others	0.2	0.5	1.6	1.5	0.5	0.5	0.8	0.5
White-firing clays	**9.4**	**10.7**	**14.0**	**13.1**	**9.4**	**13.4**	**9.2**	**15.7**
Czech Republic	1.1	1.1	0.9	0.6	0.2	0.2	0.3	0.9
Germany	0.4	0.3	0.5	0.5	2.2	4.1	4.4	11.1
Ukraine	0.2	0.4	0.1	0.1	0.3	0.3	0.2	–
United Kingdom	7.4	8.5	8.3	7.3	4.9	8.2	3.5	3.0
USA	–	–	3.1	3.6	1.6	0.3	0.3	0.4
Others	0.3	0.4	1.1	1.0	2.0	0.0	0.5	0.3
Refractory clays	**339.7**	**280.7**	**317.1**	**313.9**	**212.6**	**248.2**	**313.6**	**259.5**
China	–	0.1	0.0	0.8	–	–	0.6	0.4
Czech Republic	1.3	1.5	1.4	2.8	1.0	0.7	0.7	0.8
France	–	–	–	–	–	–	–	–
Germany	1.5	1.8	2.3	6.9	4.5	7.3	10.2	11.1
Ukraine[1]	336.8	277.3	313.4	303.4	206.8	239.9	302.1	247.2
United Kingdom	0.1	0.0	0.0	0.0	0.3	0.0	0.0	0.0
USA	–	–	–	–	–	–	–	–
Stoneware and other clays	**89.9**	**85.5**	**82.2**	**103.5**	**71.5**	**77.4**	**125.0**	**133.5**
Czech Republic	1.9	3.8	3.0	2.4	6.2	10.5	21.2	16.5
Germany	83.5	76.7	73.9	95.6	57.3	54.8	97.2	110.4
Italy	3.5	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Spain	0.1	0.2	1.0	1.4	1.4	1.5	1.9	2.3
Ukraine	0.9	–	–	–	3.6	0.2	–	–
United Kingdom	–	4.0	3.6	3.4	2.1	10.2	4.1	3.9
Others	0.0	0.8	0.7	0.6	0.9	0.3	0.6	0.4

[1] The majority is supposed to be white-firing clays, incorrectly classified as refractory clays.
Source: Central Statistical Office (GUS)

Table 12

The structure of ceramic clays importation to Poland in 1996, 2004 and 2012 [%]

Tabela 12

Struktura importu iłów ceramicznych do Polski w latach 1996, 2004 i 2012 [%]

Country/Year	1996	2004	2012
Czech Republic	40.3	0.9	4.5
Germany	27.6	24.9	32.4
Ukraine	10.7	71.7	61.4
United Kingdom	6.2	1.9	0.8
USA	13.0	0.4	0.1
Others	2.2	0.2	0.8

Source: Central Statistical Office (GUS)

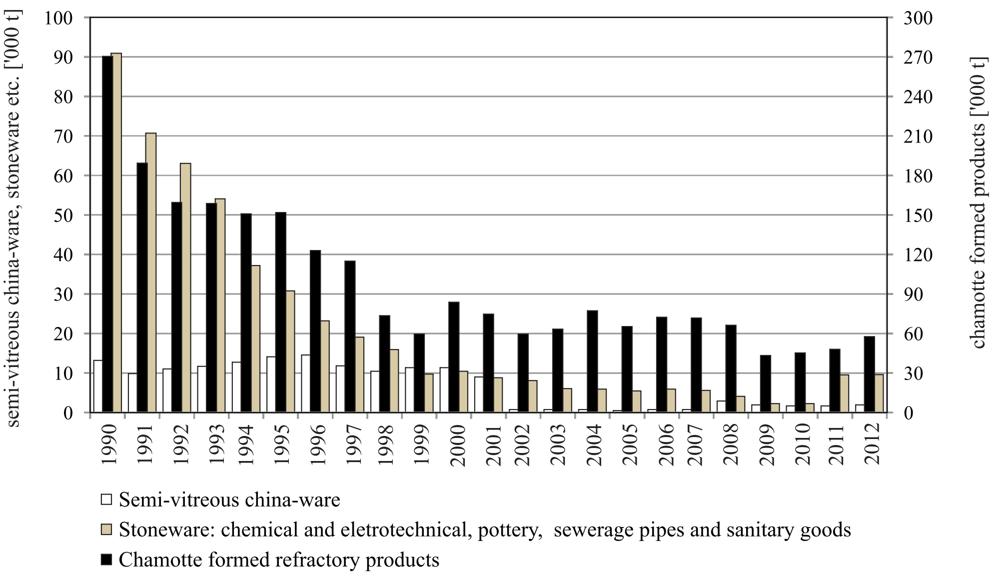

Fig. 2. Production of selected ceramic products in Poland where ceramic clays have been utilized
Source: Central Statistical Office (GUS)

Rys. 2. Produkcja wybranych wyrobów ceramicznych w Polsce,
w których wytwarzaniu użytkowane są iły ceramiczne

Table 13

Quantity and average unit values of ceramic clays imports to Poland in 2012, by country

Tabela 13

Kierunki i średnie wartości jednostkowe importu iłów ceramicznych do Polski w 2012 r.

Clay/Country/Year	Quantity ['000 t]	Unit value [PLN/t]
White firing clays		
Total imports	15.7	531
Czech Republic	0.9	752
France	0.2	924
Germany	11.1	438
Spain	0.2	1,147
United Kingdom	0.3	532
USA	0.4	2,165
Refractory clays		
Total imports	259.5	308
China	0.4	1,238
Czech Republic	0.8	742
Germany	11.1	2,990
Ukraine	247.1	184
Stoneware clays		
Total imports	133.5	229
Czech Republic	16.4	179
Germany	110.4	200
Netherlands	0.2	2,312
Spain	2.3	1,237
Ukraine	3.9	165

Source: Central Statistical Office (GUS)

Ceramic tiles have become the main assortment of ceramic products, in the production of which ceramic clays, both white-firing and stoneware, have been utilized. There has been observed a pronounced downward tendency in supply and demand for faience tiles (made of porous ceramics), manufactured with the use of white-firing ceramic clays of low sinterability. At the same time, a rapid growth in the production of stoneware tiles (containing stoneware clays in the body composition), and their gres (porcelain) variety (made of white- or light-firing clays of high sinterability) has been recorded.

In Poland both glazed and unglazed stoneware and gres tiles have been manufactured. Their total production increased in 2001–2008 by around 185%, exceeding 1.9 Mtpy. In subsequent years it ranged from 1.76 to 1.96 Mtpy (see: Figs. 1, 3), depending on domestic demand and foreign sales opportunities (at current production capacities rated at more than 2.2 Mtpy, including around 40% of gres tiles). The largest domestic producers have been: Rovese Group (until 2012 called Cersanit), controlling two leading tile manufacturers, i.e. Opoczno I (operating four plants in Opoczno, of the total production potential of around 27 Mm^2/y) and Cersanit III of Wałbrzych (with capacity of around 19 Mm^2/y), as well as Paradyż Group (five plants of total capacities of ca. 38 Mm^2/y, located in the region of Tomaszów Mazowiecki and Opoczno). The group of smaller tile producers has included: Ceramika Tubądzin, Ceramika Nowa Gala of Końskie, Końskie Group (Ceramika Końskie, Cer-Rol, CerArt Studio and Star-Gres), Polcolorit Capital Group (Polcolorit and Ceramika Marconi in Piechowice), Cerkolor, and Ceramika Pilch in Jasienica. Clinker tiles, also classified as ceramic tiles, have been manufactured on the basis of stoneware clays at around 10 factories, e.g.: Cerrad of Radom, Ceramika Tarona of Tarczyn near Warsaw, Ceramika Przyborsk near Bolesławiec and ZPS Przysucha.

An important user of white-firing clays has been also the sanitaryware industry, utilizing also kaolin and stoneware clays of lower quality in manufacturing of products, high whiteness of which after firing is not required (they are glazed). Currently on the domestic market there are six producers, dominated by Cersanit I in Krasnystaw (a subsidiary of Rovese Group, production capacity of 3.2 million pieces per year) and Sanitec Koło belonging to Sanitec-Metra (three plants in Koło, Włocławek and Ozorków of the total production potential of over 3 million pieces per year). The share of each one in the domestic sanitaryware market has been 40%. The remaining, minor manufacturers include: Roca Sanitario of Gliwice, Hybner in Środa Wielkopolska, Deger Ceramika in Jezuicka Struga near Inowrocław, and Ceramika Pilch in Jasienica near Bielsko Biała. In the years 2000–2008 the domestic production of sanitaryware increased by almost 140%, which was coupled with expansion of their foreign sales, up to 75–80% of the domestic production. However, in 2009–2012, as a result of reduced demand from Polish and foreign recipients, the production of sanitaryware diminished by 25%, down to 83,700 t last year (Fig. 1).

Products made of semi-vitreous china-ware include primarily tableware and ornamental goods (the so-called fancy goods). In recent years the domestic production of semi-vitreous china-ware, mainly carried out by Ceramika Tułowice in Tułowice, have slighty recovered, approaching 2,000 tpy last year (Fig. 2). The domestic market, however, still has been flooded by Chinese products, which even have been started to be re-exported.

The production of stoneware goods – with the exception of stoneware ceramic tiles – has been characterized by a general declining tendency resulted from reduced demand or competition from other building materials (Fig. 2). The major domestic producer of stoneware goods has been Bolesławiec Ceramic Plant, which together with numerous smaller pottery manufacturers in the Bolesławiec region, has offered pottery products, including tableware, pots and barrels (called Bolesławiec ceramics) highly appreciated also abroad. Other manufacturers have been Marywil Stoneware Plant in Suchedniów and ZMCiK Ziębice, specialized in acid-resistant stoneware goods and stoneware sewerage pipes.

Ceramic clays of refractory properties have been utilized in the refractory industry almost exclusively for the production of alumino-silicate refractories, primarily chamotte products – bricks, blocks and shapes (Fig. 2), as well as refractory mortars and mixes. The consumption of refractory clays in this branch has been characterized by a permanent downward trend, which has been associated with declining demand for chamotte products (especially in the steelmaking industry). For example, the production of shaped chamotte products decreased from around 270,000 t in 1990 to ca. 60,000 t in 1999, while in subsequent years it ranged between 60,000 and 85,000 tpy. In the years 2009–2010, as a consequence of the deep crisis in the domestic steelmaking industry, demand for these products dropped by almost 40%, with a slight improvement in recent years (Fig. 2). Around 50% of the output of raw refractory clays has been utilized for the production of burnt refractory clay (exclusively at JARO plant), while the other 50% – directly (in unprocessed form) in the refractory industry.

Taking into account the kinds of ceramic goods manufactured in Poland (from among discussed above) as well as the type and typical quantity of particular ceramic clay utilized in the production of these products, the total consumption of white-firing and refractory clays of domestic and foreign origin (including imported clays reported in CN 2508 40), can be estimated at around 540,000 t in 2012, including ca. 395,000 t of imported clays, ca. 35,000 t of domestic white-firing clays and ca. 110,000 of domestic refractory clays. Estimated structure of their consumption was as follows: gres (porcelain) and stoneware tiles – around 68%, refractories – ca. 19%, faience tiles and semi-vitreous china-ware – ca. 11%, sanitaryware and others – ca. 2%. The consumption of domestic stoneware clays for the production of above-mentioned ceramic goods in 2012 can be assumed at around 400,000 t, with ca. 93% utilized in the ceramic tiles branch, ca. 4% – in sanitaryware, and the remaining 3% – in manufacturing of other stoneware goods (except tiles).

In the following years it is expected that the demand for ceramic clays in the ceramic tiles and sanitaryware industries will stabilize at recent level or will slightly increase, the consumption of clays in the refractory industry will fluctuate depending on economic cycle with general declining tendency, while the demand for appropriate clay varieties in the semi-vitreous china-ware and stoneware goods (except tiles) production will remain marginal.

1.3. Feldspar and feldspar-quartz raw materials

In Poland a number of rocks varieties, which can be potential sources for the production of feldspar and feldspar-quartz raw materials, are known. They include (Lewicka 2010a):

- leucogranites occurring in the following deposits: Pagórki Wschodnie near Sobótka, Mrowiny near Żarów, and Kopaniec in the Izerskie foothills;
- granites, accompanied by feldspar-quartz, e.g. Pagórki Zachodnie, Strzeblów I, Graniczna, Rogoźnica, and Gniewków deposits;

— weathered coarse-grained granites from the vicinity of Szklarska Poręba and Jelenia Góra, e.g. Karpniki deposit;
— leucoporphyres in Siedlec deposit near Krzeszowice;
— porphyry tuffs in Filipowice near Krzeszowice;
— arcose in Kwaczała near Chrzanów.

The basic source of feldspathic raw materials (actually feldspar-quartz ones) are deposits located in the Strzegom-Sobótka massif (the Lower Silesia), operated by Strzeblowskie Kopalnie Surowców Mineralnych (SKSM) of Sobótka – their largest Polish manufacturer (recently from 420,000 to 450,000 tpy, i.e. 85–87% of domestic supplies, Tab. 14). The extraction of feldspar-quartz in the Sobótka region has been carried out since the eighteenth century. After the Second World War, Pagórki Wschodnie leucogranite deposit has been of the largest significance. It has been operated since 1956, basically for feldspar-quartz grits and flours utilized by the ceramic and glass-making industries. In 2011, after renewed geological reconnaissance, the operation of Stary Łom deposit was resumed (abandoned in 1960). The source of feldspar has been also granite deposits operated by SKSM, i.e.: Pagórki Zachodnie (since 1963) and Strzeblów I (since 2007). The production potential of the company approaches 500,000 tpy of grits (98% of the sales) and feldspar-quartz flour. Grits have been primarily utilized in the ceramic tile industry, while flour – both in the ceramics and glassmaking.

Before 1991, some quantities (difficult to ascertain) of feldspar-quartz raw material were recovered from run-off-mine of Andrzej kaolin deposit (Lewicka 2005). Moreover, in the years 1991–1998 the Karpniki porphyry granite deposit was operated by ZP Jopex. The raw material, offered mainly in unprocessed form, had been utilized in the production of porcelain tiles (of gres type). Attempts to obtain concentrates of stable chemical composition and better quality parameters (i.e. alkalis content >13%, and colouring compounds <0.1%) failed that – coupled with problems with sales – was a reason for cessation of the production (Lewicka 2010a). In 2000 the Pol-Skal of Kraków appeared as a new owner of the deposit that – besides the resumption of operations in 2004 – planned to build a modern processing plant offering wide range of grits and flour characterized by low content of colouring oxides for ceramics (these plans have never been realized). By 2008 the output from Karpniki deposit was gradually increasing, reaching 100,000 tpy (Tab. 14). The producer offered mainly grits of 0–8, 1–8 and 0–2 mm, obtained in course of simple mechanical processing (crushing, grinding, and classification). The majority of these products was utilized in the production of ceramic tiles. In 2009 the output diminished to 65,000 tpy, while in 2010 there was further 50% reduction, because in June this year, due to social and environmental conflicts (e.g. location of the deposit in the Rudawski Landscape Park), the operation of the deposit was indefinitely suspended.

Since the mid-1990s feldspar-quartz from Graniczna granite mine (operated by Wrocławskie Kopalnie Surowców Mineralnych – currently Eurovia) has started to be placed on the domestic market. The commercial products have been rich in alkalis, fine fractions generated in course of the production of crushed aggregates, i.e. granite sand 0–2 mm (dry and washed) and – on smaller scale – granite flour 0–1 mm, as well as waste material accumulated in the landfill (Minerals Yearbook… 2013). These raw materials started to be successfully utilized in the production of ceramic glazed tiles, biscuit, clinker tiles and building ceramics. Their sales for the ceramic industry reached the highest level (60,000–80,000 tpy) in the beginning of the 21st century, while in recent years it have ranged from 20,000 to 40,000 tpy (Tab. 14).

Table 14

Feldspar raw materials statistics in Poland [‘000 t]

Tabela 14

Gospodarka surowcami skaleniowymi w Polsce [tys. t]

Category/Year	1990	1991	1992	1993	1994	1995	1996	1997
Mining output	32.0	24.0	34.0	43.0	46.0	46.0	64.0	74.0
Total production, including:	34.0	23.8	24.3	32.9	41.4	71.3	86.1	108.1
Strzeblowskie KSM	*34.0*	*23.8*	*22.6*	*30.7*	*38.1*	*44.1*	*51.2*	*59.4*
ZP Jopex/Pol-Skal	–	–	*1.7*	*2.2*	*3.3*	*0.0*	*5.6*	*14.8*
Skalmin/Bumat(Gniewków)	–	–	–	–	–	*1.5*	*1.5*	*1.5*
Rogoźnica II et al.	–	–	–	–	–	–	–	*0.2*
Wrocławskie KSM	–	–	–	–	–	*25.7*	*27.8*	*32.2*
Jeleniogórskie KSM	–	–	–	–	–	–	–	–
Imports	14.3	11.5	19.8	26.0	26.1	32.6	37.6	42.3
Exports	–	–	0.0	0.0	0.0	0.0	0.0	0.2
Apparent consumption	48.3	35.3	44.1	58.9	67.5	103.9	123.7	150.3

Category/Year	1998	1999	2000	2001	2002	2003	2004	2005
Mining output	26.5	181.0	138.0	150.0	219.0	289.0	336.9	457.4
Total production, including:	116.7	120.1	161.2	208.6	293.0	334.4	424.5	505.2
Strzeblowskie KSM	*61.7*	*81.6*	*89.3*	*138.2*	*199.4*	*276.3*	*367.9*	*422.1*
ZP Jopex/Pol-Skal	*10.5*	–	–	–	–	–	*0.6*	*20.0*
Skalmin/Bumat(Gniewków)	–	*0.5*	–	–	–	–	–	–
Rogoźnica II et al.	*0.7*	–	–	–	–	–	*15.0*	*15.0*
Wrocławskie KSM	*43.8*	*38.0*	*65.9*	*62.4*	*83.7*	*53.1*	*35.5*	*43.3*
Jeleniogórskie KSM	–	–	*6.0*	*8.0*	*9.9*	*5.0*	*5.5*	*4.8*
Imports	50.1	79.1	114.8	185.4	197.7	221.1	265.3	288.2
Exports	0.1	0.6	0.8	0.7	1.2	1.8	2.2	2.1
Apparent consumption	166.7	198.6	275.2	393.3	489.5	553.7	687.6	791.3

Table 14 cont.

Tabela 14 cd.

Category/Year	2006	2007	2008	2009	2010	2011	2012
Mining output	431.3	497.9	599.1	445.5	513.7	550.0[e]	376.5
Total production, including:	477.6	591.8	643.7	478.0	485.1	538.2	487.2
Strzeblowskie KSM	*354.1*	*382.7*	*424.7*	*343.5*	*382.8*	*454.9*	*425.5*
ZP Jopex/Pol-Skal	*45.0*	*90.0*	*100.0*	*65.0*	*30.0*	–	–
Skalmin/Bumat(Gniewków)	–	–	–	–	–	–	–
Rogoźnica II et al.	*15.0*	*70.0*	*50.0*	*30.0*	*30.0*	*35.0*	*30.0*
Wrocławskie KSM	*58.1*	*43.9*	*62.6*	*34.1*	*35.0*	*39.7*	*22.7*
Jeleniogórskie KSM	*5.4*	*5.2*	*6.3*	*5.4*	*7.3*	*8.6*	*9.0*
Imports	287.5	326.2	323.7	276.7	324.1	412.4	364.3
Exports	5.5	2.7	5.5	9.2	8.4	10.5	8.6
Apparent consumption	759.6	915.3	961.9	745.5	800.8	940.7	841.9

[e] – estimated.
Source: producers' data, GUS

Smaller quantities of feldspar-quartz fine-grained fractions (usually 0–5 mm) have been also offered by other manufacturers of dimension stones and granite crushed aggregates, i.e.: PPU Czernica Granit, Gniewków mine or Rogoźnica II mine. Consumption of these alkali-rich raw materials, the total level of which has been estimated at 60,000–120,000 tpy, hasn't been recorded in official statistics. Their supply has remained in close correlation with the output of granite crushed aggregates. A relatively small, but gradually increasing in recent years, production of feldspar-quartz raw materials (5,000–9,000 tpy), predominantly of glass grade, has been also reported by Jeleniogórskie Kopalnie Surowców Mineralnych of Szklarska Poręba (Tab. 14).

In recent decades the volume of mining output of feldspar-quartz raw materials in Poland varied widely. In the years 1990–1998 it ranged between 30,000 and 70,000 tpy (Lewicka 2010a). The highest dynamics of its growth was recorded after 2000, when it was increasing almost continuously, approaching 600,000 tons in 2008. The years 2009–2012 brought a slowdown and large fluctuations in the mining production: in 2009 there was 25% drop, in the following two years – the rise, and in 2012 – a reduction of over 30% to the lowest level in eight years (Minerals Yearbook… 2013).

The total domestic supplies of feldspar-quartz raw materials displayed similar fluctuations as the mining production. The pace of its annual growth, which in the late 1990s ranged from 8 to 25%, in the beginning of the 2000s increased to 30–40%, following the rapidly growing demand for raw materials in the domestic ceramic tile industry (Lewicka 2003;

Lewicka and Wyszomirski 2005; Galos and Lewicka 2008). In 1998–2008 feldspar supply from domestic sources increased over fivefold, reaching unprecedented level of 640,000 tons in 2008 (Tab. 14, Fig. 3). This promoted Poland to the top ten largest tile manufacturers in the world (the fourth in Europe). In the following years, except 2011, it reached much lower levels of ca. 480,000 tpy, which was related to the weakening of the demand of basic consumers of feldspar, i.e. ceramic tiles manufacturers and – to a lesser extent – sanitaryware and glass producers.

Feldspar-quartz raw materials of domestic origin are characterized by rather inferior parameters (Lewicka ed. 2012). This has resulted in the importation of higher purity products, meeting requirements of the porcelain (Fe_2O_3 < 0.1%), sanitaryware and glass-making industries (Tab. 15).

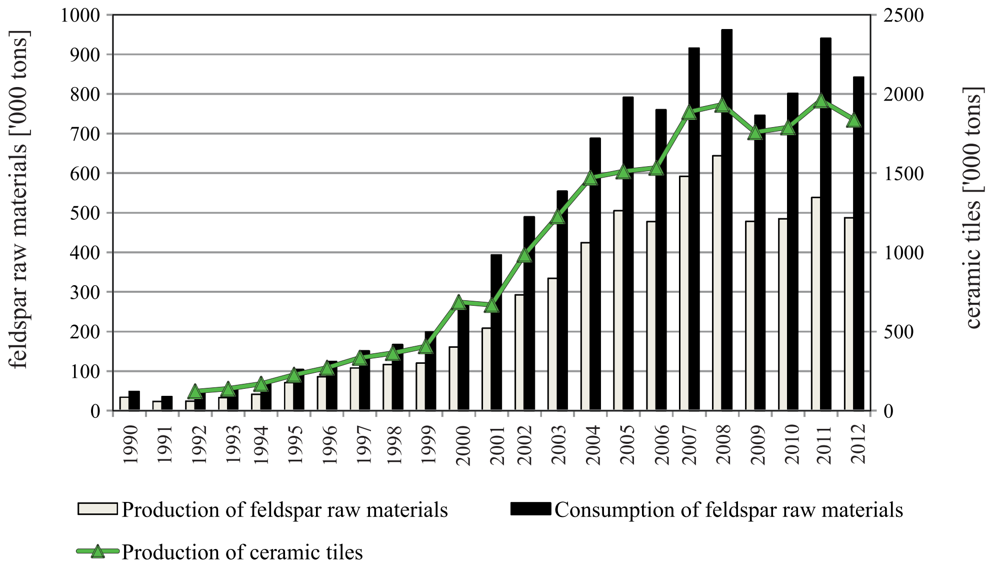

Fig. 3. The production and consumption of feldspar versus the production of ceramic tiles in Poland, 1990–2012
Source: producers' data, own calculations

Rys. 3. Produkcja i zużycie surowców skaleniowych oraz produkcja płytek ceramicznych w Polsce w latach 1990–2012

The importation of feldspar raw materials to Poland, which in 2007–2008 reached around 320,000 tpy, after 15% drop in 2009, increased to a maximum of 412,000 tons in 2011, with ca. 12% reduction to 364,000 tons last year (Tabs. 14, 17) (Minerals Yearbook… 2013). The largest deliveries have originated from Turkey and the Czech Republic (around 37% per each in 2012). There were imported feldspar flour and grits of highest quality for the porcelain industry, feldspar concentrates (<0.1% Fe_2O_3) for the production of high-quality glass, and nepheline syenite for the needs of the glass-making and sanitarywary industries (deliveries of nepheline syenite has accounted for 30–37% of the total importation). Except the scarce raw

Table 15

Specifications of selected domestic and imported feldspar raw materials

Tabela 15

Specyfikacje wybranych krajowych i importowanych surowców skaleniowych

Chemical composition [wt. %]	GS.08.D/01[1] (SKSM)	MS.063D /01[2] (SKSM)	ŽK 05[1] KMK Granit (Czech)	F501E10[1] Esan (Turkey)	RF4[1] Imerys (France)	Ž65K20[3] LB Minerals (Czech)	Ataflux 45[4] Sibelco Nordic (Norway)	Norfloat 600[5] Sibelco Nordic (Norway)
SiO_2	<78.0	74.0–78.0	73.5	69.0	75.1	72.3	56.0	68.4
Al_2O_3	>12.5	12.5–14.0	15.7	18.5	15.0	14.7	24.0	19.0
Na_2O	7.5–9.0	7.5–8.5	4.10	10.0	2.80	1.79	7.80	7.60
K_2O			4.52	0.40	3.60	9.48	8.80	2.80
Fe_2O_3	<0.5	0.2–0.4	0.47	0.14	0.17	0.20	0.10	0.10
TiO_2	<0.05	<0.05	0.06	0.30	0.02	0.05	0.10	0.002
CaO	<0.5	<0.5	0.44	0.70	0.50	0.34	1.60	1.80
MgO	<0.5	<0.5	0.09	0.20	0.05	0.06	<0.10	–

[1] – for the production of ceramic tiles, [2] – for the production of sanitaryware, [3] – mainly for the production of porcelain goods, [4] – nepheline syenite for the production of glass, [5] – feldspar of glass grade.
Source: producers' data

materials with parameters required by fine ceramics and glass technologies (low content of colouring oxides, high content of alkalis), significant quantities of raw materials of relatively lower purity have been purchased by the ceramic tile industry. This was due to high demand in this sector especially for raw materials utilized in the production of porcelain tiles (*gres porcellanato*), characterized by elevated content (40–60%) of feldspar in the ceramic body.

The largest foreign suppliers of feldspathic raw materials to Poland, including those for the production of porcelain tiles (basically sodium feldspar, i.e. with a predominance of Na_2O over K_2O in the chemical composition), have been: Turkey, the Czech Republic and Norway. The Czech Republic has delivered basically grits sourced from Halamky deposit operated by LB Minerals/Lasselsberger and Krasno deposit of KMK Granit, from Turkey there were imported mainly sodium grades manufactured by Kaltun, Esan Eczacibasi, Kalemaden et al. (Wyszomirski et al. 2012), while from Norway – potassium and sodium feldspar concentrates (until the mid–2011) as well as nepheline syenite produced by North Cape Minerals/Sibelco Nordic (Lewicka 2010b). Much smaller quantities of these raw materials have come from France (Imerys), Germany, Spain, Finland and others (Tab. 16).

The ceramic tile industry has dominated the domestic structure of feldspar and feldspar--quartz raw materials consumption. It is estimated that this branch has recently accounted for

Table 16

Structure of feldspar and feldspar-quartz raw materials supplies on the Polish market in 2012

Tabela 16

Struktura podaży surowców skaleniowych i skaleniowo-kwarcowych na rynku polskim w 2012 r.

Voivodship/Country	Supplier	Supply [‘000 t]
Total		**842**
Dolnośląskie – Poland	Strzeblowskie KSM	424
	Wrocławskie KSM	23
	Jeleniogórskie KSM	9
	Rogoźnica II et al.	30
Czech Republic	KMK Granit, LB Minerals	136
Turkey	Esan, Kalemaden, Kaltun et al.	133
Norway	Sibelco Nordic	72
France	DAM/Imerys	6
Spain	DAM/Imerys	4
Germany	AKW/Quarzwerke	4
Finland	Sibelco Nordic	1

Source: producers’ data, Central Statistical Office (GUS)

over 80% of the total demand, while the shares of the remaining users have been as follows: glass-making industry – 10%, ceramic sanitaryware – 6%, articles made of fine ceramics and electroporcelain – around 2%, chemicals, enamels et al. – 2%.

Precise determination of feldspar raw materials consumption by particular customer is difficult. This would require the knowledge on products recipes, which is a subject of closely guarded secret of each manufacturer. Furthermore, in most compositions of ceramic bodies a combination of two or more alkali-rich ingredients are blended, and sometimes modified by addition of synthetic frits. Feldspar content in the ceramic body of wall and floor tiles varies widely from 10 to 55% depending on the type of tile, while in porcelain tile body it may even reach 60%. In the recipe of other ceramic goods feldspar content can be as follows: 27–32% in hard porcelain, 22–30% in semi-vitreous chinaware, 32–36% in soft porcelain, 25–35% in sanitaryware, 15–30% in tableware, up to 90% in dental porcelain, 30–50% in electroporcelain (Bolewski et al. 1991).

The consumption of feldspathic raw materials in Poland have been a function of main customers demand, i.e. the ceramic and glass-making industries, and indirectly – a condition of the construction industry and general economic situation of the country. In the ceramic industry, due to high alkali content (Na_2O and K_2O), feldspar acts as a flux lowering temperature of firing. In the glass-making industry feldspar plays mainly a role of Al_2O_3 carrier, which acts as a stabilizer reducing tendency to vitrification, and is responsible for transparency, mechanical strength, durability and chemical resistance of glass (Lewicka 2010a).

A systematic increase in supply and demand for raw materials in question (both of domestic and foreign origin) recorded since the mid-1990s has explicitly correlated with boom in the construction industry, which had been stimulated by investment allowances and incentives coupled with expansion and modernization of the domestic ceramic tile industry. The rapid growth of the tiles production, especially of their porcelain variety, as well as of ceramic sanitaryware, has resulted in multiple rises in the demand for feldspar and feldspar-quartz raw materials (Fig. 3). Since the late 1990s to 2008 the consumption of these raw materials increased over nine-fold, reaching 960,000 tpy. In 2009, as the first indications of global financial crisis and economic slowdown appeared, a decrease of over 20% (to around 745,000 tpy) in consumption of feldspathic raw materials was reported. That was the first drop in demand in Poland for many years. This was directly related to decreased number of new buildings of commercial and private use, and therefore weakening of demand for building materials such as ceramic tiles, sanitaryware, and construction glass. Subsequent years have seen the upsurge in feldspar consumption, up to a maximum of 940,000 tpy in 2011 (Minerals Yearbook… 2013), because it appeared that the effects of the world crises less influenced the pace of economic growth in Poland than it was expected. These beliefs have been verified in 2012, which was reflected in the slowdown in the construction industry and 10% decline in feldspathic raw materials consumption.

The ceramic tile industry has utilized mainly feldspar-quartz grits from Strzeblowskie KSM and – between 2004 and 2010 – also from Pol-Skal, as well as fine-grained granite waste material from Graniczna mine and several other Lower Silesian granite mines. In addition, feldspar-quartz raw materials have been imported from the Czech Republic and Turkey, which was a consequence of location of the majority of ceramic tile plants (ca. 70% of the domestic production) in the region of Tomaszów Mazowiecki–Opoczno–Końskie, i.e. in relatively large distance from domestic suppliers. The Lower Silesian manufacturers of ceramic tiles (representing around 20% of domestic production), i.e. Cersanit III in Wałbrzych, Polcolorit and Ceramika Marconi in Piechowice near Jelenia Góra, due to favourable location relative to national feldspar-quartz manufacturers (including alkali-rich fine-grained materials generated in course of crushed aggregates production in granite mines), have been mainly supplied by domestic producers, like Upper Silesian tile plants (Pilch from Jasienica, and Jopex from Zabrze – until 2009).

Other important consumers of feldspathic raw materials in the ceramic industry have been manufacturers of fine ceramics, especially tableware porcelain (feldspar constitutes ca. 25% of porcelain body, while kaolin and quartz – the rest). The producers of porcelain tableware have utilized feldspathic raw materials of the highest purity, imported from Norway, Germany, France, and Finland. Their largest consumer has been Lubiana (Pomorskie voivodship), smaller ones – Chodzież (Wielkopolskie voivodship), Ćmielów (Świętokrzyskie voivodship), and plants in the Lower Silesia. Three manufacturers of electroporcelain that have utilized the best quality feldspathic raw materials from Norway, Germany, France, and Finland, are of much smaller importance as their consumers.

Relatively small amounts of feldspar-quartz of domestic origin (the highest grades offered by Strzeblowskie KSM) have been utilised in the sanitaryware industry, because this branch has based on feldspar imported from abroad. The most modern and the largest plants, using fast firing technology, i.e. Sanitec Koło and Cersanit, have introduced nepheline syenite of Norwegian origin as a carrier of alkalis in the batch, while in some of the smaller plants Turkish feldspars have been utilized.

Nepheline syenite (or high purity feldspar concentrate) can be also used for the production of glass. However, the glassmaking industry has also consumed feldspar-quartz flour from Strzeblowskie KSM and Jeleniogórskie KSM, as well as feldspar imported from the Czech Republic, Norway and other countries.

In recent years the demand for feldspathic raw materials in Poland has been covered in 55–60% from domestic sources, while the rest has come from abroad. Despite high level of consumption of these raw materials, especially in the ceramic tile industry, the proportions of their future supplies from national and foreign sources shouldn't change. The essential part of these supplies will continue to originate from indigenous sources as the quality of offered products meets the requirements of ceramic tiles manufacturers.

The largest domestic producer – Strzeblowskie Kopalnie Surowców Mineralnych, supplying 340,000–420,000 tpy of feldspar-quartz raw materials in recent years (i.e. 44–48% of domestic demand), has production capacity of 500,000 tpy, and it is able to substantially increase the output. Moreover, by implementing an innovative system of run-off-mine homogenization, the quality of offered products has improved considerably (especially in terms of the content of colouring oxides, as well as stability and repeatability of parameters) (Lewicka ed. 2012).

The analysis of the origin of imported raw materials indicates that their purchase has been justified not only by the quality, which is crucial in some applications, but above all – by price. From among foreign suppliers of feldspar to Poland, the lowest unit values of deliveries have been from the Czech Republic (174 PLN/t in 2012) and Turkey (201 PLN/t, an increase from 164 PLN/t in 2010), slightly higher – from France (Tab. 17). The importation from France – after significant reduction to less than 1,000 tons in 2004 – began to recover (to 6,000 tpy in 2012). It can be assumed that, due to high quality and relatively low unit cost, this raw material could be a future alternative for feldspar delivered from other countries.

Domestic mineral resource base of feldspar is rather poor. Although anticipated economic resources at the end of 2012 amounted to 137.5 Mt, but only 5.5 Mt of them constituted economic resources of deposits in operation (Pagórki Wschodnie, Karpniki and Stary Łom) (Mineral Resources Datafile… 2013). This figure doesn't include resources of raw materials occurring in granite deposits, which have been also utilized as a source of feldspar-quartz.

Table 17

Quantity and average unit values of importation of feldspathic raw materials to Poland in 2012, by country

Tabela 17

Kierunki i średnie wartości jednostkowe importu surowców skaleniowych do Polski w 2012 r.

Country	Quantity [‘000 t]	Unit value [PLN/t]
Total imports	**364.3**	**250**
Feldspar	*285.0*	*199*
Czech Republic	136.2	174
Turkey	133.0	201
France	6.2	315
Spain	4.4	333
Germany	3.5	476
Finland	1.5	633
Nepheline syenite	*79.3*	*433*
Norway	79.2	432

Source: Central Statistical Office (GUS)

Prospects for the discovery and start-up of new deposits of feldspathic raw materials are limited to the regions that have been already explored, basically in the Izerskie foothills (total prognostic resources of around 59 Mt, Bilans perspektywicznych… 2011) and deposits already documented in this area. However, due to environmental reasons (landscape parks, Natura 2000) the possibilities of extending the existing reserve base are small. Taking into account the scarcity of occurrences of high-potassium feldspar varieties in Poland, a real opportunity for development of the deposit of raw material rich in potassium feldspar (7–9% K_2O), can be associated with Niemcza region (Kawia Góra – prognostic resources of 3.3 Mt). This would require, however, performing the detailed geological recognition. Another potential source of alkali-rich raw materials is granitoide occurring in the Eastern Sudetes region. Valuable source of feldspar is light, partly weathered leucogranite, outcropping in the wall of crystalline limestone’s quarry in Sławniowice near Nysa. Preliminary examinations of this raw material have demonstrated its suitability for the production of ceramic tiles, also of their porcelain variety (Lewicka 2010a).

Nevertheless, the possibilities to satisfy the demand for feldspar-quartz raw materials from domestic sources, in particular with regard to the ceramic tiles industry needs, should be assessed as quite promising. A vital prerequisite for this is the production potential of the largest domestic supplier of feldspar-quartz raw materials – Strzeblowskie Kopalnie Surowców Mineralnych. The renewal of the Karpniki operation can also be taken into account (however it seems unlikely by 2020), as well as supplies of alkali-rich fine-grained fractions generated in course of granite crushed aggregates production for the ceramics that can reach 100,000 tpy. In 2020 perspective, the total output of feldspar-quartz from domestic sources can amount to around 700,000–750,000 tpy. A risk to this scenario may pose the development of secondary materials utilization, e.g. glass cullet, which has been used by some foreign ceramics manufacturers as a cheaper and more energy-effective substitute of feldspar (Feytis 2012), although in the case of Polish ceramic industry a perspective of implementation of such a solution seems to be rather far.

On the demand side it is assumed that, after a period of stagnation caused by slowdown in economic growth in Poland and recession in the European Union countries, the rise in consumption of feldspar is awaited. It will be linked with anticipated recovery in the construction industry and finishing of the ongoing investments as well as with expected growth of ceramic goods exportation from Poland, especially to Eastern and Central Europe, as well to Germany.

An assumed growth in demand for feldspathic raw materials will result in the need for their supplementary importation, in the range of 300,000–350,000 tpy, basically of high purity grades for the production of porcelain and electro-porcelain and nepheline syenite for the sanitaryware industry. The technologies of above-mentioned goods manufacturing require raw materials characterized by generally lower contents of colouring oxides and higher share of alkalis than typical for raw materials of domestic origin. The largest deliveries will continue to originate from the Czech Republic (basically due to logistic issues). Important suppliers will presumably remain also: Turkey, which – despite considerable distance from Polish customers – has offered relatively cheap raw materials characterized by high proportion of alkalis and low share of colouring oxides, as well as Norway – leading producer of nepheline syenite.

1.4. Silica sand for glass production

Silica sand, being the basic commodity for the glassmaking industry, must meet stringent requirements, concerning mainly chemical composition, especially content of colouring oxides (Fe_2O_3 and TiO_2), as well as grain size distribution (basic grain fraction should be between 0.1 mm and 0.5 mm). They are almost monomineral quartz sands, derived from deposits of high quality sands or sandstones in course of multi-stage processing and beneficiation. Depending on quality they are utilized in the production of different types of glass and glass products. The purest grades, i.e. Sp and 1 classes, containing less than 0.03% colouring oxides (TiO_2 + Fe_2O_3), are consumed in the production of optical glass and laboratory glassware made of transparent silica glass. Sand of class 1 (seldom of class 2) is applied for the production of lead crystal glass. Sand of class 3 is used mainly in tableware glass manufacturing, whereas class 3 and less frequently class 4 – for window glass and other architectural glass. The lowest grades of sand are utilized for the production of containers and glass insulators.

The implementation of *float* method in the production of flat glass resulted in more stringent requirements related to a quality of mineral raw materials, mainly in terms of grain size distribution (90% of grains should be between 0.1 mm and 0.4 mm), SiO_2 content above 99% (the domestic glass industry requires >98.5% SiO_2), Fe_2O_3 content in the range of 0.02–0.05%, as well as Al_2O_3 – 0.25–0.35% (Galos ed. 2009). The latter parameter makes necessary to use raw materials of higher classes – 2 and 3 – in accordance to BN-80/6811-01 standard.

Poland has relatively abundant resources of silica sand satisfying almost all the needs of the domestic glass industry. The exception are the highest grades of sand that have been imported in small amounts from Germany, and cheaper raw materials – irregularly purchased in Ukraine by Jarosław Glassworks for the container glass production (Galos and Burkowicz 2009). On the other hand, significant increase in the domestic quartz sand output, especially after 2007, has resulted in exportation of supply surpluses to neighbouring countries, such as the Czech Republic and Slovakia, in an amount representing approximately 10% of the domestic production (Tab. 18).

The production of glass sand in Poland is concentrated in three major centres located in two main areas of the raw material occurrence: the region of Tomaszów Mazowiecki in central Poland and the vicinity of Bolesławiec in the Lower Silesia. In the area of Tomaszów Syncline there are two large suppliers of glass-grade sand: TKSM Biała Góra in Smardzewice near Tomaszów Mazowiecki (since 2007 in the structure of Quarzwerke Capital Group), and Grudzeń Las – a part of the Atlas Group in Łódź. In recent years total supplies of both manufacturers have exceeded 1.3 Mt per year, accounting for almost 65% of the domestic production. More than 60% of supply from this region has originated from TKSM Biała Góra, which by the use of cyclones and spiral classifiers has provided glass sand of classes 3 to 1a. Grudzeń Las has manufactured glass sand of classes 3–4 (Tab. 19), obtained in course of processing of raw material from two deposits (Grudzeń Las and Piaskownica Zajączków Wschód deposits) at Syski and Grudzeń Las plants. In recent years the total production of both plants has ranged between 530,000 and 670,000 tpy.

Outside the Tomaszów Syncline, a large and significant producer of high-quality quartz sand is Osiecznica Glass Sand Pit and Processing Plant, owned, just like TKSM Biała Góra, by Quarzwerke. The run-off-mine from Osiecznica deposit, after enrichment in scrubbers, spiral and electro-magnetic separators, is processed into the best quality glass-grade sands of 1 to 3 classes (Tab. 19). In recent years their production has reached 600,000–620,000 tpy. The highest purity sand from Osiecznica (of 1 and 1a classes) has been exported as well. Glass-grade sand has been also obtained as a by-product of kaolin processing from Maria III deposit near Bolesławiec, operated by KSM Surmin-Kaolin of Nowogrodziec. Until 2005 this material had been sent to Osiecznica plant for further processing. Since 2006, when Surmin-Kaolin launched a new line for sand processing, the raw material has been beneficiated on site. About 100,000 tpy of sand, in terms of the content of colouring oxides corresponding to the class 3, could be produced there. In the last three years their output ranged between 75,000 and 87,000 tpy (Tab. 18, 20).

Table 18

Glass sand statistics in Poland [‘000 t]

Tabela 18

Gospodarka piaskami szklarskimi w Polsce [tys. t]

Year	1990	1991	1992	1993	1994	1995	1996	1997
Mining output*	995.0	992.0	966.0	942.0	1,150.0	1,104.0	1,314.0	1,256.0
Production	859.0	875.0	783.0	824.0	759.0	874.0	1,111.2	1,124.4
Imports	NA	NA	1.6	1.9	1.4	2.1	5.8	9.2
Exports	NA	NA	4.0	0.6	13.7	8.9	18.3	13.3
Consumption	859.0	875.0	780.6	825.3	746.7	867.2	1 098.7	1,120.3

Year	1998	1999	2000	2001	2002	2003	2004	2005
Mining output*	1,487.0	1,535.0	1,622.0	1,456.0	1,579.0	1,812.0	1,883.0	1,969.0
Production	1,375.2	1,418.1	1,531.5	1,423.8	1,235.7	1,401.5	1,478.5	1,782.6
Imports	8.0	8.4	9.6	14.2	52.1	51.1	9.7	12.3
Exports	13.8	26.7	38.6	14.8	21.2	42.7	71.6	87.0
Consumption	1,369.4	1,399.8	1,502.5	1,423.2	1,266.6	1,409.9	1,416.6	1,707.9

Year	2006	2007	2008	2009	2010	2011	2012
Mining output*	1,970.0	2,067.0	2,207.0	1,793.0	1,995.0	2,290.0	2,149.0
Production**, including:	1,955.9	2, 057.1	2,076.2	1,795.6	1,924.8	2,232.2	2,211.5
TKSM Biała Góra	791.9	750.5	715.5	682.7	684.7	774.0	851.2
Grudzeń Las	275.0	324.6	399.7	435.9	533.1	666.2	546.3
KiZPPS Osiecznica[e]	789.0	872.0	861.0	597.0	632.0	717.0	727.0
KSM Surmin-Kaolin	100.0	110.0	100.0	80.0	75.0	75.0	87.0
Imports	11.1	15.8	14.7	7.9	6.9	12.1	19.2
Exports	107.0	227.6	270.2	156.0	205.3	231.3	209.5
Consumption	1,860.0	1,845.3	1,820.7	1,647.5	1,726.4	2,013.0	2,021.2

NA – not available.
[e] – estimated.
* Mining output only from the deposits of quartz sand of glass grade.
** Central Statistical Office’s data corrected for overdeclared production of TKSM Biała Góra.
Source: Central Statistical Office (GUS), own calculation

Table 19

Comparison of quality parameters of glass sand offered by main domestic producers

Tabela 19

Porównanie parametrów jakościowych piasków szklarskich głównych dostawców krajowych

Producer/Product/Parameter	SiO_2	Fe_2O_3	TiO_2	Al_2O_3	Humidity [%]	The content of grains 0.1–0.5 mm [%]
	[wt. %]					
KiZPPS Osiecznica						
Class I/0.08 – OS 03/08	99.5	0.008	0.02	0.15	0.2	94
Class I – OS 03/10	99.5	0.010	0.02	0.20	0.2	94
Class Ia/0.012 – OS 03/12	99.4	0.012	0.03	0.30	0.2	90
Class Ia/0.015 – OS 3/15	99.4	0.015	0.03	0.30	0.2/5.5	90
Class II – OS 03/20	99.3	0.020	0.05	0.40	5.5/0.2	90
Class III – OS 14/30	98.5	0.030	0.08	0.80	5.5/0.2	87
TKSM Biała Góra						
Class Ia	99.4	0.015	0.03	0.30	wet or dry	
Class II	99.3	0.020	0.05	0.40	wet or dry	
Class III	98.5	0.030	0.08	0.80	wet or dry	
Class IV	98.5	0.050	0.08	0.80	wet or dry	
Grudzeń Las						
Class III	99.3	0.025	0.06	0.11	wet or dry	94
Class IV	99.2	0.035	0.07	0.12	wet or dry	94

Source: producers' data

Table 20

Structure of glass sand supply in Poland in 2012

Tabela 20

Struktura podaży piasków szklarskich w Polsce w 2012 r.

Voivodship/country	Supplier	Supply [‘000 t]
Łódzkie/Poland	TKSM Biała Góra	851
	Grudzeń Las	546
Dolnośląskie/Poland	KiZPPS Osiecznica	727[e]
	KSM Surmin Kaolin	87
Wielkopolskie/Poland	Ardagh Glass Ujście	29[e]
Czech Republic		10
Germany		6

[e] – estimated.

Source: Central Statistical Office (GUS), producers' data

Table 21

Mining output of sand from glass-grade sand deposits in Poland [‘000 t]

Tabela 21

Wydobycie piasków ze złóż piasków szklarskich w Polsce [tys. t]

Plant/Year	1990	1991	1992	1993	1994	1995	1996	1997
Total mining output	**995**	**992**	**966**	**942**	**1,150**	**1,104**	**1,314**	**1,256**
TKSM Biała Góra*	304/61	403/49	319/33	340/50	485/17	540/51	692/87	633/131
KiZPPS Osiecznica	482	448	457	453	470	414	484	505
Grudzeń Las*	0/403	0/255	0/284	0/271	0/317	0/325	0/572	0/605
Ardagh Glass Ujście	76	80	73	36	85	101	99	74
Ardagh Glass Wyszków	33	20	17	24	21	27	24	25
HS Kunice in Żary (Lutynka – Soczewka R2)	13	17	16	15	26	22	15	19
Świniary Sand Mine	87	24	83	73	63	–	–	–

Plant/Year	1998	1999	2000	2001	2002	2003	2004	2005
Total mining output	**1,487**	**1,535**	**1,622**	**1,456**	**1,579**	**1,812**	**1,883**	**1,969**
TKSM Biała Góra*	783/82	724/136	762/64	691/71	798/45	821/0	842/3	937/46
KiZPPS Osiecznica	580	699	721	629	563	772	857	859
Grudzeń Las*	0/492	0/637	2/690	2/524	118/444	148/634	96/708	92/685
Ardagh Glass Ujście	77	74	100	97	67	53	69	64
Ardagh Glass Wyszków	31	38	36	37	32	18	19	16
HS Kunice in Żary (Lutynka – Soczewka R2)	16	–	–	–	–	–	–	–

Plant/Year	2006	2007	2008	2009	2010	2011	2012
Total mining output	**1,970**	**2,067**	**2,207**	**1,793**	**1,995**	**2,290**	**2,149**
TKSM Biała Góra*	826/8	782/17	762/18	729/10	764/38	927/160	850/105
KiZPPS Osiecznica	867	958	946	624	695	789	797
Grudzeń Las*	182/783	240/848	377/854	397/750	471/724	524/1023	473/823
Ardagh Glass Ujście	84	74	101	27	48	45	29
Ardagh Glass Wyszków	12	14	21	16	17	5	–

* After the mark ‘/’ the output from foundry sand deposits was given.
Source: Mineral Resources Datafile

The production of quartz sand of the lowest class 6, obtained without any enrichment, has been conducted in Ujście Noteckie II and Wyszków-Skuszew mines, and directly consumed in the neighbouring glassworks, i.e. Ardagh Glass Ujście and Ardagh Glass Wyszków respectively. The quality of obtained sand complies with the requirements set by coloured glass manufacturers. The production of these mines, which generally hadn't exceeded 100,000 tpy, in 2012 significantly declined to less than 30,000 t, coming exclusively from Ujście Noteckie mine (Tab. 21).

In 2005–2008 the mining output of quartz sand in Poland significantly increased, up to around 2 million tpy, mainly due to the production development in Biała Góra and Osiecznica plants (Tab. 21). In 2006–2008 also the production of commercial grades of glass sand reached 2 Mtpy. The year 2009, however, brought a sharp decline in supplies of the raw material and slightly smaller decrease in the production of glass sand, to around 1.8 million tons (Tabs. 18, 21), due to economic crisis and – in consequence – reduced demand from producers of construction glass and glass containers (Fig. 4). In 2010 a revival in the mine production of quartz sand was observed (to almost 2 Mt), while in 2011 it approached 2.3 Mt. It should be mentioned that sand for glassmaking has been obtained also from deposits of foundry sands, therefore – where appropriate (i.e. for Grudzeń Las and Biała Góra) – the output from both sources has been specified in Table 21.

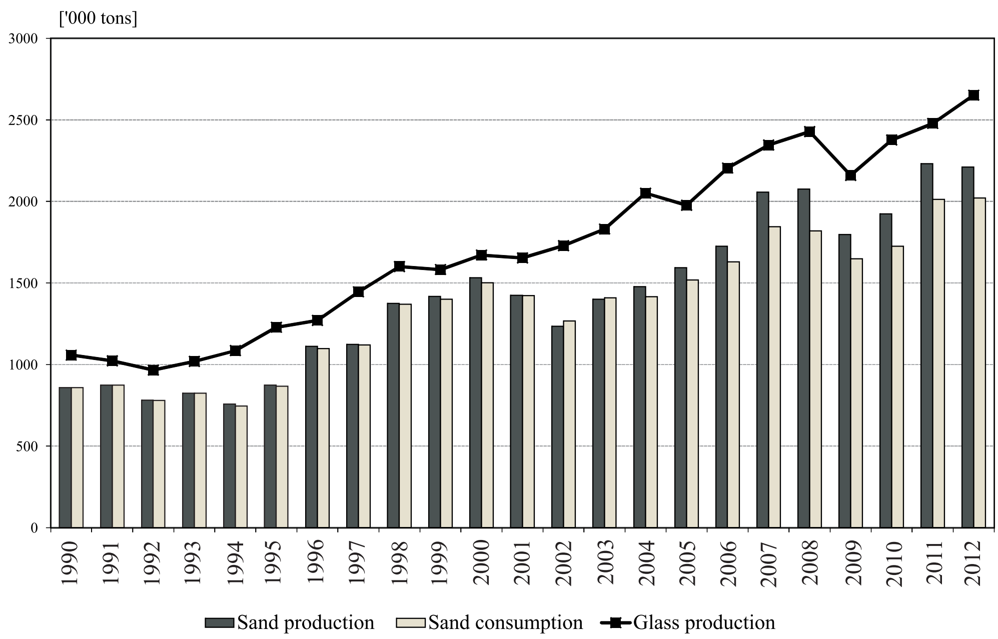

Fig. 4. Production and consumption of glass sand versus glass production in Poland, 1990–2012
Source: Central Statistical Office (GUS), producers' data, own calculations

Rys. 4. Produkcja i zużycie piasków szklarskich oraz produkcja szkła w Polsce w latach 1990–2012

Domestic supply has been supplemented by irregular imports ranging from 7,000 to 15,000 tpy, mainly from Germany, Ukraine and the Czech Republic (Tabs. 18, 22). Since 2003, significant exports of glass sand from Poland have been also recorded, which in recent years has varied between 160,000 and 270,000 tpy (Tab. 18). That has been a result of supply surpluses on the domestic market.

The largest amounts of glass-grade sand have been undoubtedly consumed in the production of glass packaging. Assuming the theoretical content of silica in the container glass at 71–73% and taking into account current anticipated consumption of recycled glass cullet at the level of 350,000 t, the demand for sand in this industry has probably ranged from 730,000 to 750,000 tpy, of which ca. 250,000 tpy accounted for Owens-Illinois Glassworks of Jarosław, about 150,000 tpy for Ardagh Glass of Gostyń, and per around 50,000–70,000 tpy for Owens Illinois Glassworks of Antoninek, Ardagh Glass of Ujście Noteckie, and Warta Glass of Sieraków (Tab. 23), whereas the remaining ca. 140,000 tpy, for smaller glassworks such as: PolAmPac HS Orzesze, Ardagh Glass Wyszków, Stolzle Częstochowa, HS Sława and others. The major suppliers of raw materials for the above-mentioned glassworks have been KiZPPS Osiecznica, TKSM Biała Góra, and Grudzeń Las.

In the case of float glass, containing in its composition almost 73% of silica of 99% purity, it can be estimated that in recent years the amount of quartz sand consumed by operating glassworks has ranged from 650,000 to 750,000 tpy. Each of three big glassworks, i.e. Pilkington Sandoglass, Polfloat Saint Gobain, and Guardian Industries, has probably utilized about 180,000–220,000 tpy of sand, mainly of 2 and 3 classes, whereas the rest has been

Table 22

Volume and average unit value of glass sands imports to Poland in 2012, by country

Tabela 22

Kierunki i średnie wartości jednostkowe importu piasków szklarskich do Polski w 2012 r.

Country	Quantity [t]	Unit value [PLN/t]
Total imports	**19,168**	**539**
Czech Republic	10,877	212
Germany	6,011	749
France	979	534
Norway	254	3,538
Denmark	189	493
Sweden	194	1,975
Italy	165	943
Belgium	126	4,314

Source: Central Statistical Office (GUS)

Table 23

Estimated geographic structure of glass-grade sand consumption in major glassworks in Poland in 2010

Tabela 23

Szacunkowa struktura geograficzna zużycia piasków szklarskich w większych hutach szkła w Polsce w 2010 r.

Voivodship	Glassworks	Estimated consumption ['000 t]
Kujawsko-Pomorskie	Irena[1] Glassworks	20–30
Łódzkie	Euroglas Polska	200
Mazowieckie	Ardagh Glass Wyszków	20–30
Podkarpackie	O-I Produkcja Polska, Jarosław Glassworks	240–250
	Krośnieńskie Glassworks Krosno	20–30
Śląskie	Polfloat Saint Gobain	180–220
	Guardian Industries Poland	180–220
	PolAmPac HS Orzesze	40–50
	Jedlice Glassworks (Warta Glass Group)	20–30
	Stolzle Częstochowa	<20
Świętokrzyskie	Pilkington Sandoglass	180–220
	HS Sława	<20
Wielkopolskie	O-I Produkcja Polska, Antoninek Glassworks	50–60
	Ardagh Glass Gostyń	<150
	Ardagh Glass Ujście	60–70
	Sieraków Glassworks (Warta Glass Group)	60–70

[1] Production finished in 2012.

consumed by a new plant of Euroglas in Ujazd (Tab. 23). The main suppliers of raw materials for these glassworks have been TKSM Biała Góra and Grudzeń Las.

Sands of class 2 and higher, mainly from Osiecznica mine, have been consumed for the production of technical glass and tableware glass in total amounts of around 50,000 tpy, mainly by Irena glassworks in Inowrocław and KHS Krosno. Unfortunately, the forecast for this sector that constitutes only 2% of the total production of glass products in Poland, is not optimistic due to growing imports of tableware glass. Last year it surpassed the level of domestic production. Moreover, the largest producer – KHS Krosno declared bankruptcy by liquidation in March 2009 that may affect other companies belonging to Krosno Group, i.e. of Jasło and Tarnowiec. In 2010 also HS Irena declared bankruptcy, finally ceasing the production and in early 2012.

The demand for glass-grade sand can be fully satisfied by domestic suppliers, both in terms of quality and quantity. At the end of 2012 the total resources of recognized deposits amounted to 621.7 Mt, including 505.8 Mt (81%) in the deposits of the Tomaszów Syncline. This is the area of the greatest resource potential in the country, both in terms of documented resources as well as prospects for new deposits discovery. The resources of seven deposits under operation were 188.9 Mt (Mineral Resources Datafile… 2013). Taking into account recent mining output of around 2 Mtpy, the sufficiency of the resources of extracted deposits exceeds 90 years. Analysis of the possibilities for expanding the resource base indicates the prognostic resources of over 210 Mt and prospective resources approximately 64 Mt (Bilans perspektywicznych... 2011). They occur almost exclusively in the Tomaszów region. The prognostic resources of glass sand and sandstone constitute ca. 30% of the documented reserves, whereas the prospective resources – of only 10%.

A problem associated with providing the glass industry with raw materials is the location of glass-grade sand deposits, limited actually to only two regions, i.e. the Tomaszów Syncline and Bolesławiec. Another characteristic phenomenon is the fact of progressive concentration of the production of quartz sand for the glassmaking industry in the hands of one entity, i.e. Quarzwerke (Osiecznica and Biała Góra, over 70% of sand supply in Poland).

The growing production of glass, especially glass containers and flat glass, as well as new investments made in recent years, i.e. the commissioning of Euroglas glassworks in Ujazd near Łódź, expansion of O-I plant in Jarosław, modernization of Krosglass glassworks in Krosno, together with planned investments, including growth in the production of Stolzle glassworks in Częstochowa, launching a new glassworks of container glass by Saint-Gobain in Łódź, and the construction of another factory of car windows – Pilkington Automotive in Chmielów, creates an optimistic scenario for development of the glass industry in Poland. This will result in steadily increasing demand for glass-grade sand, with maintaining the existing sources of supply, i.e. basically domestic deposits. The new investments will result in increased production capacities of the domestic glass industry (with the exception of the so-called processed/deeper worked glass, i.e. double-glazed units and automotive glass) up to around 2.8–3.0 million tpy by 2020.

When analyzing the glass-grade sand and glass products output in Poland in the past twenty years, it is possible to distinguish two ten-year lasting phases of development, characterized by different growth rates. In 1990–2000, the average annual increase in the production of glass and quartz sand was 4.9% and 6.6% respectively, while in the following decade, despite a significant increase in 2006–2008, average annual growth rates were lower: 3.8% and 4.6% respectively.

An important feature stimulating the demand for flat glass in the domestic market has been the growth in the construction investments, both residential and commercial (most surfaces of external facades and elements of interior design are made of glass). The significant impact on the demand for flat glass and glass wool have had also programs of thermal insulation works conducted and planned on a large scale in the existing housing stocks, including – among others – replacements of traditional windows for new ones of low emission, and insulation of residential buildings. An important factor determining the demand for glass is also wealth of society, coupled with development of individual construction and increased consumer spending, including purchasing new cars, in the construction of which the processed (deeper worked) glass has been used. Demand for flat glass is particularly sensitive to economic cycles, because it depends on the condition of the building and automotive industry.

An essential factor affecting the glass production is the relationships of the Polish economy with the European Union members, especially Germany, because the considerable amounts of glassware have been exported from Poland to that country. In 2006–2008, exports accounted for 31–32% of the total domestic production of glass, but in 2009 – only 26% while in 2010 – 24%. Possible further reduction of glass exports could undoubtedly adversely affect the development of the production volume.

1.5. Limestone flours for glass applications

Marbles and limestone are the basic carbonate raw materials, from which limestone flours utilized in the production of glass are obtained. Despite large limestone resources, domestic sources of raw materials for manufacturing of limestone flours of glass grade are limited because the majority of available limestone rocks are of insufficient purity, particularly in terms of too high content of colouring oxides, mainly Fe_2O_3. The removal of these oxides from the raw material is often difficult technologically and economically not viable (Wyszomirski and Galos 2007). The requirements for limestone flours for the glass industry are defined by BN-74/6812-01 standard (Tab. 24). In terms of chemical composition there are four grades distinguished: S (<0.05% Fe_2O_3), E (<0.06% Fe_2O_3), G1 (<0.1% Fe_2O_3), and G2 (<0.4% Fe_2O_3, Tab. 24), while due to particle size – two grades: coarse (over 30% residues on the sieve of 0.10 mm) and fine-grained (up to 70% of particles below 0.075 mm).

Table 24

The requirements for limestone flours for the production of glass (acc. to BN-74/6812-01 standard)

Tabela 24

Wymagania stawiane mączkom wapiennym dla przemysłu szklarskiego (wg normy BN-74/6812-01)

Grade	Contents [%]		
	CaO	Fe_2O_3	Parts insoluble in HCl
S	54.0–55.5	<0.05	<1.00
E	54.0–55.5	<0.06	<2.00
G1	54.0–55.5	<0.10	<2.00
G2	>50.0	<0.40	<4.00

The principal domestic sources of carbonate raw materials for glass-grade limestone flours have been for many years:

— Devonian limestone from Trzuskawica, Sitkówka, Ostrówka and Ołowianka deposits in the Świętokrzyskie region,
— some types of Upper Jurassic limestone from Sobków, Bukowa, and Chęciny-Wolica deposits in the Świętokrzyskie region,
— Cambrian crystalline limestones of the Wojcieszów region in the Lower Silesia.

Limestone utilized as a component of glass batch has been obtained in Poland by the following producers:

— ZPW Trzuskawica, currently exploiting Trzuskawica deposit, and until 2003 also Sobków deposit;
— Lhoist operating Bukowa deposit (until recently also Wojcieszów deposit);
— Nordkalk, extracting two limestone deposits: Chęciny-Wolica, Ostrówka and Ołowianka.

Limestone from the Sitkówka region, exploited by ZPW Trzuskawica, which has been the main source for the production of limestone flours, is of pelitic structure, high compactness, and low porosity. Iron impurities that are largely associated with presence of clay minerals, can be easily removed by rinsing with water. Therefore, the purest types of Devonian limestone from Trzuskawica deposit could be utilized for the production of limestone flour with a content of Fe_2O_3 below 0.1%, corresponding to G1 grade of limestone flour (Tab. 24). The majority of limestone flours for the domestic glass industry have been obtained from Devonian limestone of Trzuskawica deposit.

Another raw material for limestone flours of glass grade manufacturing has been Jurassic limestone of the Świętokrzyskie region, mainly from Sobków and Bukowa deposits. These pelitic rocks, characterized by high $CaCO_3$ contents, are suitable for the production of glass flours of E grade (Tab. 24). However, such flours have been sourced only from Bukowa, because the extraction of Sobków deposit was ceased in 2003.

Limestone flours of G2 grade had been obtained in course of selective exploitation of bright variety of Cambrian crystalline limestone deposits of Wojcieszów region in the Lower Silesia (Wyszomirski and Galos 2007). However, their extraction has been recently halted. Limestone flours of that grade have been produced from Devonian limestone of Ostrówka and Ołowianka deposit and from Jurassic limestone of the Chęciny-Wolica deposit (both operated by Nordkalk).

The volume of total production of limestone flours has been always difficult to ascertain because all kinds of flour, both for ceramic and other applications (including large amounts of carbonate sorbents for energy sector) have been recorded by the Central Statistical Office in one statistical item together with raw limestone and its derivatives. In the years 1992–2004 the Central Statistical Office reported the volume of domestic limestone flours supplies, but these figures didn't include all their varieties, particularly products for the energy sector (Tab. 25). According to data from the Polish Lime Association available for 2006 the production of limestone flours for the glass industry reached 168,000 tons (Tab. 26),

Table 25

Limestone flour production in Poland ['000 t]

Tabela 25

Produkcja mączek wapiennych w Polsce [tys. t]

Year	1990	1991	1992	1993	1994	1995	1996
Production	NA	NA	325	349	396	359	357

Year	1997	1998	1999	2000	2001	2002	2003	2004
Production	354	395	438	685	522	524	635	567

Rok	2005	2006	2007	2008	2009	2010	2011	2012
Production	1827[1]	1516[1]	NA	NA	NA	NA	NA	NA

NA – not available.
[1] Including limestone sorbents for flue gas desulphurization in power plants.
Source: Central Statistical Office (GUS)

Table 26

Structure of limestone flour supply for the glass industry in Poland in 2006

Tabela 26

Struktura podaży mączek wapiennych dla przemysłu szklarskiego w Polsce w 2006 r.

Voivodeship/Country	Supplier	Supply ['000 t]
Total		**168**
Świętokrzyskie/Poland	ZPW Trzuskawica	97
	Nordkalk	18
	Lhoist Bukowa	23
Czech Republic	Omya	30

Source: Polish Lime Association, Central Statistical Office (GUS)

while the total output of all types of limestone flours (including sorbents for flue gas desulphurization) exceeded 1.5 Mt (Tab. 25).

The development of the glass production resulted in significant increase in demand for limestone flours of glass grade, and as a consequence in growth of their supply from domestic plants. Unfortunately, the information on these supplies is fragmentary and available only for very few manufacturers, e.g. Nordkalk's plants output in 2007 and 2009 was 17,600 and 21,000 tpy respectively (>16% increase). The majority of limestone flours for the domestic glass industry have been recently obtained from Devonian limestone of Trzuskawica deposit (about 60% of supply), while smaller quantities have been sourced from Jurassic limestone of Bukowa and Chęciny-Wolica deposits, as well as from Devonian limestone of Ostrówka and Ołowianka deposit (Tab. 27). The detailed statistics of limestone flours production for the glass industry have not been available since 2007. The total current volume of their output could be estimated at 180,000–190,000 tpy. Limestone flours in Verocal and Omyacarb grades, produced by Vapenna plant in the Czech department of Omya, have been also available on the Polish market. Due to their high prices and very high quality they have been intended to be used only in the production of special glass.

Table 27

Comparison of quality parameters of glass-grade limestone flours manufactured by major domestic producers

Tabela 27

Porównanie parametrów jakościowych mączek wapiennych dla przemysłu szklarskiego wytwarzanych przez głównych krajowych producentów

Parameter [%]	Lhoist Bukowa[1] (Jurassic)	Trzuskawica (Devonian)	Nordkalk Chęciny-Wolica (Jurassic)	Nordkalk Ostrówka&Ołowianka (Devonian)
$CaCO_3$	>97.0/98.0	>98.0	>97.74	>98.15
SiO_2 and insoluble parts	<1.5/0.7	<1.0	<0.96	<0.62
$MgCO_3$	<0.5/0.4	<0.8	<0.56	<0.55
Fe_2O_3	<0.1/0.07	<0.06	<0.14	<0.13
Al_2O_3	NS/<0.2	<0.4	<0.21	<0.18
Humidity/H_2O content	<0.2/0.2	<0.2	<0.3	<0.3
Granulation	100% < 0.2 mm/ /100% < 2 mm	100% < 0.3 mm	93.6% < 0.09 mm	100% < 1.5 mm

NS – not studied.
[1] For fine-grained/coarse product.
Source: producers' data

Limestone flours have been utilized mainly in the production of container and flat glass, and – in smaller amounts – in tableware glass manufacturing. In the glass batch they act as calcium oxide (CaO) carrier, which is an essential component in the technology of soda-lime glass production. This compound, together with MgO, can be also introduced to the batch by the addition of another mineral raw material – dolomite. The presence of magnesium oxide in the composition of most glasses is advantageous, excluding special grades, such as optical glass and optical fibres, where it is unacceptable. The content of calcium oxide in the composition of typical container glass is 9–12%, while that of magnesium oxide is only

0.2–3.5%. For example, to introduce 7% CaO and 3% MgO, it is necessary to add about 5% of limestone flour (50 kg per ton of glass) and about 14% of dolomite flour (140 kg per ton of glass). In float glass batch, the content of 6.0–8.5% of CaO is required, while in tableware glass and crystal glass much lower addition can be utilized.

Taking into account the above-mentioned assumptions, domestic limestone flour consumption in the float glass production can be estimated at about 80,000 tpy, while in the container glass industry (including recycled glass cullet) – at 80,000–120,000 tpy and in tableware glass manufacturing – at several thousand tpy. Taking into consideration the recent level of production of different types of glass, the total consumption of limestone flours in the glassmaking can be ranged between 170,000 and 200,000 tpy. Domestic supply of limestone flour for glass application, recently estimated at 180,000–190,000 tpy, has been supplemented by their small importation, in quantities difficult to establish* (probably up to 20,000 tpy). That has referred primarily to high quality limestone flours with very fine particle size manufactured outside Poland at Omya's foreign departments, especially in Vapenna plant in the Czech Republic (e.g. Verocal and Omyacarb grades). Assuming optimistic scenario of the glass industry development a further moderate increase in demand for glass-grade limestone flours can be expected in the near future.

1.6. Dolomite flours for glass applications

The main raw materials for the production of dolomite flours for the glass and ceramic industries in Poland are the purest types of dolomitic marble. Existing large resources of dolomite and dolomitic marble cannot be a source for the production of glass-grade flours of the highest purity, in particular due to very high content of Fe_2O_3 in these rocks, similarly to the raw materials for limestone flours manufacturing. The requirements for such limestone flours have been defined by BN-80/6714-17 standard, but currently their parameters have been usually agreed individually between the manufacturer and the customer. According to the above-mentioned standard the following grades of dolomite flours have been distinguished: five grades of various grain size distribution as well as eight grades referred to chemical composition (mainly to Fe_2O_3 content), including two special grades 1S and 2S (Tab. 28). The glass industry has utilized only four grades, i.e.: 1, 1S, 2, 2S. Due to the particle size distribution the following grades have been specified: 0–0.04 mm (M 0.040), 0–0.063 mm (M 0.063), 0–0.125 mm (M 0.125), 0–0.25 mm (M 0.25) and 0–0.5 mm (M 0.50). The maximum acceptable content of Fe_2O_3 in the case of 1S and 1 standard is 0.2%, for grades 2 and 2S – 0.4%, while the total amount of $MgCO_3$ + $CaCO_3$ should be higher than 97% and 95% respectively (Tab. 28). Humidity of the manufactured flours should not exceed 1%.

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* Limestone flours are not separately classified in the nomenclature of foreign trade CN, therefore the level and origin of their importation is difficult to ascertain.

Table 28

The requirements for dolomite flours of glass grade (acc. to BN-80/6714-17 standard)

Tabela 28

Wymagania stawiane mączkom dolomitowym dla przemysłu szklarskiego (wg normy BN-80/6714-17)

Grade	Contents [wt. %]		
	MgO	Fe_2O_3 [max.]	$MgCO_3 + CaCO_3$ [min.]
1 and 1S	19–23	0.2	97
2 and 2S	19–23	0.4	95
3	19–23	1.0	90
4	17.5–23	2.0	80
5	16–23	4.0	80
6	13–23	6.5	80

The glass-grade dolomite flour has been sourced from the purest rocks mined in Ołdrzychowice and Rędziny plants. Rędziny mine, operated by Jeleniogórskie Kopalnie Surowców Mineralnych (JKSM), has provided 190–250 tpy of dolomitic marble. In the nearby Pisarzowice processing plant, as well as in another Jarnołtówek processing plant, the company has produced 100–150 tpy of dolomite flour (in 1, 1S, 2 grades), as well as significant amounts of Ca-Mg carbonate fertilizers (Minerals Yearbook… 2013). The output of dolomitic marble from the Ołdrzychowice-Romanowo deposit operated by Omya of Warsaw (previously Kambud of Ołdrzychowice) in the last two years rose significantly to above 500 tpy. The plant has delivered the highest quality grits, as well as small amounts of dolomite flour of 2 and 2S grade, while the Jasice grinding plant near Ożarów (Świętokrzyskie voivodeship), also belonging to this company, has manufactured dolomite flour of 1 and 1S grade in a very wide range of particle size, from very fine 2 µm to coarse (median 13–50 µm). They have been utilized as fillers in the production of adhesives, paints, coatings, plastics, cosmetics, as well as glass and glass fibres. Some dolomite grits have been also sold as a raw material for manufacturing of terrazzo or (higher purity grades) for the production of dolomitic flours in grinding plants operated by other companies. A similar application has had the dolomitic marble from the nearby Nowy Waliszów Soczewka C deposit, extracted irregularly by Omya.

The total production of dolomite flours for various applications in Poland has been estimated at 400,000–500,000 tpy (no official data available, Tab. 29). The majority of them, i.e. coarse grades, have been utilized in the glass industry, while very fine grades – as a filler in other applications. Dolomite fillers utilized in the paint industry and for the production of joints, adhesives and mortars in the construction industry, have been manufactured at Grudzeń Las and ZPSChiM Piotrowice of Zawichost from dolomite grits derived from Ołdrzychowice-Romanowo deposit (Tab. 30).

Table 29

Dolomite flours statistics in Poland [‘000 t]

Tabela 29

Gospodarka mączkami dolomitowymi w Polsce [tys. t]

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Production	402.1	384.5	353.0	350.0	428.2	352.4	468.0	NA	NA	NA	NA	NA	NA
Imports	95.7	83.3	104.1	124.5	120.6	129.3	147.0	166.5	177.1	140.0	133.2	98.2	132.7

NA – not available.
Source: Central Statistical Office (GUS)

Table 30

Comparison of quality parameters of dolomite flours manufactured by major domestic producers

Tabela 30

Porównanie parametrów jakościowych mączek dolomitowych wytwarzanych przez głównych krajowych producentów

Parameter [%]	Omya Jasice Plant – Omyadol 15-JA	Omya Romanowo Plant – Omyadol 5-RO	Grudzeń Las PG–20/PG-15	ZPSCHiM Piotrowice II P-10S
$CaMg(CO_3)_2$	> 5.0	>95.0	97.28	>91.4
MgO	<19.0	NS	19.27	<19.5
CaO	<29.0	NS	31.92	<32
Fe_2O_3	<0.3	<0.4	<0.17	<0.2
The content of parts insoluble in HCl	<2.5	<3.8	<0.42	<3.0
Brightness	>90.5	>91.0	NS	89.0
Humidity	<0.3	<0.2	<0.5	<0.2
The average particle size (d50%)/*(for d98%)	14 μm	6 μm	18–22 μm*/13–17 μm*	3 μm

NS – not studied.
Source: producer’s data

Significant quantities of flours, in particular these of the highest purity (with <0.05% Fe_2O_3), have been imported, mainly from Slovakia, Norway, and sometimes from the Czech Republic, Estonia, and Germany. In recent years this importation has ranged between 130,000 and 180,000 tpy (Tab. 31). They have been mostly utilized in the glass industry, and sometimes as fillers in paints, plastics, rubber, and construction materials.

Table 31

Quantity and average unit value of dolomite flours imports to Poland in 2012, by country

Tabela 31

Kierunki i średnie wartości jednostkowe importu mączek dolomitowych do Polski w 2012 r.

Country	Quantity [t]	Average unit value [PLN/t]
Total imports, including:	**132.7**	**100**
Germany	0.3	1,114
Norway	9.7	397
Slovakia	121.7	67

Source: Central Statistical Office (GUS)

The total consumption of high quality dolomite flours (with 0.05–0.40% of Fe_2O_3) in the domestic glass industry can be estimated at 450,000–500,000 tpy. The majority of their supplies have come from domestic plants: Omya and Jeleniogórskie KSM. It has been partly supplemented by imports, mainly from Slovakia and the Czech Republic. Dolomite flours are basically applied in the float glass production, where they constitute 10–20% of glass batch. They have been consumed by three the largest flat glassworks: Pilkington Sandoglass in Sandomierz (Świętokrzyskie voivodship), Polfloat Saint Gobain in Dąbrowa Górnicza – Strzemieszyce (Silesia voivodship), and Guardian Industries Poland in Częstochowa (Silesia voivodship) – probably in amounts approaching 80,000 tpy in each of them, which most recently have been joined by the fourth float plant – Euroglas Polska in Ujazd near Tomaszów Mazowiecki.

For the majority of glass types the presence of magnesium oxide in the batch is advantageous. The exclusion are special glasses, such as optical glass and optical fibres, where it is unacceptable. The typical container glass batch contains 0.2–3.5% MgO combined with 9–12% CaO, whereas in chemical composition of float glass batch MgO constitutes 4% and CaO – 8.5%. Therefore, the consumption of dolomite flour may be estimated at 250,000–300,000 tpy in float glass and at 160,000–200,000 tpy in container glass (taking into account recycled glass cullet). The total domestic consumption of dolomite flours in glass applications may range between 450,000 and 500,000 tpy.

The resources of exploited Ołdrzychowice-Romanowo deposit amounted to more than 41 Mt, while the resources of Rędziny exceeded 12 Mt (as of 31 December 2012, Mineral Resources Datafile… 2013). Taking into account their recent mining output of over 750,000 tpy, the sufficiency of these resources can be estimated at more than 70 years. Considering the possibilities for development of resources of dolomitic marble appropriated for glass applications, three zones with total prognostic and prospective resources of around 160 Mt in Kłodzko region (the Lower Silesia) have been outlined (Bilans perspektywicznych... 2011):

1) dolomitic marble of Mielnik–Waliszów syncline with deposits of Nowy Waliszów––Soczewka C and Nowy Waliszów–Soczewka D;
2) dolomitic-calcite marble of Żelazna syncline with the deposits of Wapniarka, Słupiec, Romanowo Górne, Romanowo–Waliszów;
3) dolomitic marble of Romanowo syncline with Ołdrzychowice–Romanowo deposit.

1.7. Quartz, quartzite and quartz-schist

The applications of quartz, quartzite and quartz-schist are determined by contents of SiO_2 and adverse admixtures (e.g. Fe_2O_3, Al_2O_3, TiO_2). Quartz is an important component of the batch in the production of chinaware and electrical porcelain as well as glazes of various ceramic goods, whereas quartzite and quartz-schist are utilized in manufacturing of siliceous refractory materials.

Quartz for the ceramic and glass industries is extracted primarily from various types of quartz veins occurring in the magmatic and metamorphic rocks in the Lower Silesia. In these applications the content of SiO_2 should exceed 99.5%, while maximum acceptable content of colouring oxides is 0.01% Fe_2O_3 and 0.01% TiO_2. Vein quartz is utilized in the form of fine flour. Important feature of this raw material is very high reactivity, much appreciated in ceramics (Wyszomirski and Galos 2007). However, in recent years domestic consumers more frequently have utilized quartz flour obtained in course of grinding of high purity silica sand.

Quartz products have been manufactured in Poland in variable amounts, with the maximum volume of 66,000 tons in 2001. Their recent production has stabilized at the level of 5,000–7,000 tpy (Tab. 32). In the years 1990–2008 it was principally sourced from vein quartz deposits in the Lower Silesia, i.e. Stanisław in the Rozdroże Izerskie (until 1992 the only one extracted in Poland), Taczalin near Legnica (since 1993), and Krasków near Świdnica (since 2000). Over the past twenty years the mines belonged to different owners. Until 2000 Stanisław mine was operated by Jeleniogórskie Kopalnie Surowców Mineralnych (JKSM) in Szklarska Poręba. The raw material was processed into ca. 20,000 tpy of quartz flour of various grain sizes, utilized primarily in the manufacture of porcelain. Taczalin mine was operated by Adam Rak, and afterwards by KWARCE (KGHM Polska Miedź subsidiary). The raw material from Taczalin deposit, as well as since 2000 from Stanisław (as it was purchased by KWARCE), until 2005 was processed at the company's processing plant in Mikołajowice. The plant offered quartz breakstone and key aggregate (>8 mm) for the production of ferrosilicon, quartz grits (0.4–5 mm and 5–20 mm) for chinaware, refractories and construction materials (resinous floors, special concrete, dry mortars), as well as quartz flour (<0.4 mm) for the manufacture of chinaware, glazes, chemicals, paints and varnishes. Krasków deposit was operated in the years 2000–2008 by PEZM Magma, manufacturing quartz breakstone and key aggregates for the production of ferrosilicon (ca. 25% of the total), as well as grits for chinaware and the construction industry (mortars, resinous floors).

Since 2008 no vein quartz deposit has been operated in Poland. This has resulted in increased importation as well as growing consumption of quartz flour obtained in course of grinding of pure silica sand. It is estimated that domestic supplies of the latter have oscillated around 10,000 tpy in recent years, while in the late 1990s it could had been only a few thousand tons per year. Important producers of these commodities have been Strzeblowskie Kopalnie Surowców Mineralnych (SKSM) and Grudzeń Las. SKSM's flour has been manufactured since the early 1980s from silica sand of Osiecznica deposit in five grades (MK.030/001, MP.040/001, MK.056/001, MK.075/001, MK.100/001) of the following chemical composition: min. 99 % SiO_2, <1% Al_2O_3, <0.05% Fe_2O_3, <0.05% TiO_2, and average grain size up to: 30 μm, 40 μm, 56 μm, 75 μm, and 100 μm. These grades have been utilized in the ceramic industry as a component of ceramic bodies and glazes. Grudzeń Las has been the supplier of quartz flour since 2005 (grinding plant was previously owned by Atlas). The offered products, containing 98.5–99.1% SiO_2 and 0.06–0.1% Fe_2O_3, have been primarily utilized in the production of frits added to glaze in course of ceramic goods glazing.

Table 32

Quartz, quartzite and quartz-schist statistics in Poland [‘000 t]

Tabela 32

Gospodarka kwarcem, kwarcytami oraz łupkami kwarcytowymi w Polsce [tys. t]

Year	1990	1991	1992	1993	1994	1995	1996	1997
Mining output	438.5	334.0	260.0	443.0	634.0	683.0	622.0	504.0
Quartz	*29.0*	*24.0*	*28.0*	*43.0*	*54.0*	*39.0*	*57.0*	*62.0*
Quartzite	*375.0*	*292.0*	*219.0*	*376.0*	*570.0*	*635.0*	*557.0*	*438.0*
Quartz-schist	*34.5*	*18.0*	*13.0*	*24.0*	*10.0*	*9.0*	*8.0*	*4.0*
Production	248.8	213.5	148.3	195.9	259.3	255.7	325.6	234.0
Quartz	*33.4*	*28.8*	*30.6*	*55.6*	*39.9*	*14.2*	*24.7*	*22.9*
Quartzite	*188.8*	*166.6*	*104.4*	*128.8*	*208.0*	*233.0*	*293.9*	*204.6*
Quartz-schist	*26.6*	*18.1*	13.3	11.5	11.4	8.5	*7.0*	*6.5*
Imports	19.1	8.4	1.6	6.1	4.6	6.7	9.0	5.7
Quartz	*3.9*	*1.3*	*1.4*	*0.8*	*1.8*	*2.7*	*3.6*	*4.3*
Quartzite	*15.2*	*7.1*	*0.2*	*5.3*	*2.8*	*4.0*	*5.4*	*1.4*
Exports	–	–	0.0	15.9	81.5	82.0	132.9	52.0
Quartz	–	–	–	–	*0.6*	*0.0*	*12.9*	*6.0*
Quartzite	–	–	*0.0*	*15.9*	*80.9*	*82.0*	*120.9*	*46.0*
Consumption	267.9	221.9	149.9	186.1	182.4	180.4	201.7	187.7

Table 32 cont.

Tabela 32 cd.

Year	1998	1999	2000	2001	2002	2003	2004	2005
Mining output	418.0	445.0	495.3	321.0	258.8	435.6	546.7	531.8
Quartz	*34.0*	*49.0*	*90.0*	*67.0*	*25.0*	*40.0*	*66.0*	*18.0*
Quartzite	*379.0*	*396.0*	*398.0*	*252.0*	*231.0*	*393.0*	*471.0*	*503.0*
Quartz-schist	*5.0*	–	*7.3*	*2.0*	*2.8*	*2.6*	*9.7*	*10.8*
Production	226.4	194.7	234.4	182.1	61.8	150.8	162.7	103.3
Quartz	*19.5*	*23.0*	*52.2*	*65.9*	*27.0*	*32.8*	*37.1*	*15.8*
Quartzite	*203.8*	*171.7*	*176.7*	*114.2*	*32.0*	*115.4*	*115.9*	*86.0*
Quartz-schist	*3.1*	–	*5.5*	*2.0*	*2.8*	*2.6*	*9.7*	*1.5*
Imports	4.9	15.6	12.9	72.6	27.5	89.1	88.7	68.3
Quartz	*3.8*	*3.3*	*4.8*	*3.1*	*1.5*	*1.6*	*8.0*	*9.5*
Quartzite	*1.1*	*12.3*	*8.1*	*69.5*	*26.0*	*87.5*	*80.7*	*58.8*
Exports	40.5	64.9	54.4	58.6	19.4	43.4	22.9	6.4
Quartz	*0.9*	*2.2*	*26.5*	*31.4*	*3.1*	*15.3*	*5.3*	*3.1*
Quartzite	*39.6*	*62.7*	*27.9*	*27.2*	*16.3*	*30.1*	*17.6*	*3.3*
Consumption	190.8	145.4	192.9	195.1	69.9	194.5	228.5	165.2

Year	2006	2007	2008	2009	2010	2011	2012
Mining output	558.8	650.5	631.1	637.5	1,223.4	1,654.4	1,085.2
Quartz	*3.0*	*1.0*	–	–	–	–	–
Quartzite	*545.0*	*640.0*	*624.0*	*634.0*	*1,221.0*	*1,614.0*	*1,057.0*
Quartz-schist	*10.8*	*9.5*	*7.1*	*3.5*	*2.4*	*40.4*	*28.2*
Production	32.3	53.9	79.8	26.1	40.5	53.3	59.1
Quartz	*13.9*	*7.0*	*6.5*	*5.0*	*5.6*	*6.1*	*5.3*
Quartzite	*16.9*	*46.1*	*72.5*	*20.4*	*34.2*	*46.5*	*53.2*
Quartz-schist	*1.5*	*0.8*	*0.8*	*0.7*	0.7	0.7	0.6
Imports	32.4	96.3	100.4	22.3	104.2	148.5	147.5
Quartz	*8.8*	*8.1*	*9.9*	*8.0*	*8.4*	*3.9*	*3.3*
Quartzite	*23.6*	*88.2*	*90.5*	*14.3*	*95.8*	*144.6*	*144.2*
Exports	0.3	0.5	0.3	0.1	7.7	41.8	34.6
Quartz	*0.3*	*0.5*	*0.3*	*0.1*	0.1	*0.0*	*0.2*
Quartzite	–	–	–	–	*7.6*	*41.7*	*34.4*
Consumption	64.4	149.7	179.9	48.3	137.0	160.0	172.0

Source: Central Statistical Office (GUS), Mineral Deposit Datafile, producers' data

Table 33

Quartz and quartzite imports to Poland, by country [‘000 t]

Tabela 33

Kierunki importu kwarcu i kwarcytów do Polski [tys. t]

Country/Year	1990	1991	1992	1993	1994	1995	1996	1997
Total imports	19.1	8.4	1.6	6.1	4.6	6.7	9.0	5.7
quartz	*3.9*	*1.3*	1.4	0.8	1.8	2.7	3.6	4.3
quartzite	*15.2*	*7.1*	0.2	5.3	2.8	4.0	5.4	1.4
Belgium	–	–	0.0	0.0	–	0.1	–	0.1
Germany	3.8	1.3	1.4	0.8	1.3	2.0	2.6	3.1
Italy	–	–	–	–	–	–	–	–
Norway	–	–	0.0	–	0.4	0.4	0.8	0.9
Ukraine	15.2	7.1	0.2	5.3	2.8	4.0	5.1	1.1
Others	0.1	0.0	0.0	0.0	0.1	0.2	0.5	0.5

Year	1998	1999	2000	2001	2002	2003	2004	2005
Total imports	4.9	15.6	12.9	72.6	27.5	89.1	88.7	68.3
quartz	*3.8*	*3.3*	4.8	3.1	1.5	1.6	8.0	9.5
quartzite	*1.1*	*12.3*	8.1	69.5	26.0	87.5	*80.7*	*58.8*
Belgium	0.1	0.0	0.2	0.2	0.2	0.2	0.1	0.2
Germany	2.7	2.0	2.2	1.7	1.2	1.2	2.6	1.0
Italy	–	–	–	0.5	0.1	0.1	0.1	0.1
Norway	0.9	0.6	1.4	0.3	–	–	5.0	7.6
Ukraine	0.3	11.7	7.9	69.5	25.7	87.1	79.7	58.7
Others	0.9	1.2	1.2	0.4	0.0	0.1	0.2	0.1

Year	2006	2007	2008	2009	2010	2011	2012
Total imports	32.4	96.3	100.4	22.3	104.2	148.5	147.5
quartz	*8.8*	*8.1*	*9.9*	*8.0*	*8.4*	*3.9*	*3.3*
quartzite	*23.6*	*88.2*	*90.5*	*14.3*	*95.8*	*144.6*	*144.2*
Belgium	0.1	0.1	0.2	0.2	0.2	0.4	0.3
Germany	1.1	1.5	18.8	1.5	1.8	2.0	2.7
Italy	0.8	0.7	0.6	0.8	0.1	0.0	0.1
Norway	6.7	5.7	6.7	5.1	6.0	1.4	0.3
Ukraine	23.5	88.0	73.1	14.1	95.6	144.2	144.1
Others	0.2	0.3	1.0	0.6	0.5	0.5	0.3

Source: Central Statistical Office (GUS)

Domestic demand for the highest grades of quartz has been covered by imports. The total level of foreign supplies, especially of quartz flours, has never exceeded 10,000 tpy (Tab. 33). Their traditional supplier has been Germany, while in the years 2004–2010 the major deliveries of these raw materials for the porcelain industry originated from Norway. The Norwegian commodities replaced quartz flour of domestic origin, supplied from Mikołajowice plant by 2005. Norwegian quartz flours came from Sibelco Nordic plant in Lillesand, where quartz was recovered in course of pegmatite flotation. Unfortunately, due to the closure of the mine in June 2011, these supplies decreased to 300 tonnes in 2012. This resulted in growth in importation of more expensive quartz flours from Germany, as well as increased utilization of domestic silica sand of high quality. Moreover, negligible amounts of quartz have been imported from Italy and Belgium (Tab. 33).

The average unit values of quartz products imported to Poland have ranged widely from 174 to 809 PLN/t, depending on grade and origin of purchased commodities. The prices of quartz products (mostly quartz flours) from Norway generally varied between 200 and 300 PLN/t and were considerably lower than unit values of quartz flours imported from Germany, which generally fluctuated between 400 and 600 PLN/t (Tabs. 34, 35).

Table 34

Average unit values of quartz and quartzite imports to Poland from selected countries [PLN/t]

Tabela 34

Średnie wartości jednostkowe importu kwarcu i kwarcytów do Polski z wybranych kierunków [zł/t]

Country/Year	1992	1996	2000	2004	2005	2006	2007	2008	2009	2010	2011	2012
quartz	*181*	*517*	473	174	*267*	*264*	*236*	*222*	*296*	*278*	*736*	*809*
quartzite	*1,300*	*266*	156	39	38	*41*	*34*	*38*	*31*	*32*	*43*	*54*
Germany (quartz)	158	400	528	544	584	774	611	51	538	580	766	676
Norway (quartz)	182	343	495	278	267	264	236	222	296	278	305	3,278
Ukraine (quartzite)	–	43	71	39	38	41	34	38	31	32	43	54

Source: Central Statistical Office (GUS)

The total consumption of quartz products, mostly in the form of quartz flour, ranged from 20,000 through 40,000 tpy until 2006, with the reduction to 8,000–16,000 tpy in recent years. Decrease in demand for these commodities has been related to a deep crisis in the domestic porcelain tableware sector, the production of which was reduced from 40,000–50,000 tpy to ca. 30,000 over the last twenty years (Tab. 36). Actually, the annual consumption of quartz flour has been probably higher by at least several thousand tonnes, as the flour has been manufactured directly in the mills of ceramic plants on the basis of silica sand from Osiecznica. The volume and the structure of quartz products consumption in Poland is difficult to ascertain because the information about the quantity and origin of commodities

Table 35

Quantity and average unit values of quartz and quartzite imports to Poland in 2012, by country

Tabela 35

Kierunki i średnie wartości jednostkowe importu kwarcu i kwarcytów do Polski w 2012 r.

Country	Quantity ['000 t]	Unit value [PLN/t]
Total imports	**147.5**	–
quartz	3.3	809
quartzite	144.2	54
Belgium	0.3	1 077
Germany	2.7	676
Italy	0.1	2 023
Norway	0.3	3 278
Ukraine	144.1	54

Source: Central Statistical Office (GUS)

utilized in particular ceramic or glass plant is comercially sensitive. However, it is known that quartz flours are basically utilized in the tableware production, where they constitute 20–30% of ceramic batch (Bolewski et al. 1991). The demand for quartz in this application has been estimated at below 10,000 tpy in recent years, with Lubiana, Ćmielów, Chodzież, and some plants in the Lower Silesia as principal recipients. Smaller consumers have been three domestic manufacturers of electrical porcelain (ZPE Zapel, Radpol Elektroporcelana, and Argillon Polska) with total output of 5,000–8,000 tpy (Tab. 36). Assuming that quartz content in these products constitute 10–30% of ceramic body (Burkowicz at al. 2013), its consumption can be estimated at 1,000–2,000 tpy. After termination of the quartz flours production in Stanisław and Taczalin, as well as closure of Norwegian mine, the main component of the batch in the production of tableware and electrical porcelain became quartz sand from Osiecznica mine and quartz flours imported from Germany. The main domestic suppliers of quartz flours utilized in the production of glazes of various ceramic goods as well as frits added to glaze have been Strzeblowskie KSM, supplying ceramic plants in the Lower Silesia as well as Grudzeń Las in the Opoczno area. The total consumption in this application has not exceeded a few thousand tonnes per year, with a QiumiCer Polska (Spanish OuimiCer Group subsidiary) in Opoczno as its prominent recipient. Some amounts of quartz flour have been utilized by Krosglass in Krosno, the producer of glass fibre as well as other manufacturers of special glass.

Any significant growth of the domestic demand for quartz flours in ceramics or changes in current directions of their supplies in the near future have not been anticipated. However, a possible increase in consumption of quartz flour from Osiecznica deposit may be assumed.

Table 36

The production of major industries utilizing quartz, quartzite and quartz-schist in Poland [‘000 t]

Tabela 36

Produkcja głównych branż użytkujących surowce kwarcowe, kwarcyty i łupki kwarcytowe w Polsce [tys. t]

Product/Year	1990	1991	1992	1993	1994	1995	1996	1997
Siliceous refractories	43.1	26.4	16.3	24.0	18.8	22.6	15.7	11.7
Porcelain, including:	43.4	37.2	32.6	36.4	37.9	41.3	45.2	44.3
Tableware	*33.2*	*28.2*	*25.3*	*28.4*	*30.9*	*34.3*	*37.5*	*37.7*
Electrical porcelain	*10.2*	*9.0*	*7.3*	*8.0*	*7.0*	*7.0*	*7.7*	*6.6*

Product/Year	1998	1999	2000	2001	2002	2003	2004	2005
Siliceous refractories	9.0	7.3	9.6	7.8	5.5	6.9	12.2	6.2
Porcelain, including:	45.4	46.5	48.9	50.3	48.7	43.4	45.6	44.7
Tableware	*39.4*	*40.6*	*43.0*	*43.9*	*42.2*	*40.7*	*40.3*	*38.9*
Electrical porcelain	*6.0*	*5.9*	*5.9*	*6.4*	*6.5*	*2.7*	*5.3*	*5.8*

Product/Year	2006	2007	2008	2009	2010	2011	2012
Siliceous refractories	5.1	6.2	5.7	3.1	2.8	31.1	24.9
Porcelain, including:	37.8	39.3	32.8	29.4	34.0	31.7	32.3
Tableware	*32.2*	*33.0*	*27.1*	*24.0*	*25.4*	*23.7*	*24.3*
Electrical porcelain	*5.6*	*6.3*	*5.7*	*5.4*	*8.6*	*8.0*	*8.0*

Source: Central Statistical Office (GUS)

Moreover, also the reopening of some Lower Silesian vein quartz mines could be also expected, e.g. Stanisław, which has been recently purchased by Hedar of Łaziska Górne.

At the end of 2012 seven deposits of vein quartz with total resources of 6,564,000 t have been recognized in Poland (Mineral Resources Datafile… 2013). Three of them have been developed (Stanisław, Taczalin, Krasków), while the other four were extracted on irregular basis in the past. There are also some prospects for new deposits discovery in five prognostic areas near Legnica, Świdnica and Lwówek Śląski with total resources 2,870,000 tons, and four perspective areas near Legnica and Lwówek Śląski with total resources 1,330,000 tons (Bilans perspektywicznych… 2011).

Commercial term ‘industrial quartzite’ refers to solid rocks rich in SiO_2 (>97%), regardless of their origin, i.e. both thermally metamorphosed quartz rocks (from the petrographical point of view properly named quartzite) as well as sedimentary rocks (quartzite sandstone) (Wyszomirski and Galos 2007). Traditional application of industrial quartzite has been the production of siliceous refractory materials. However, nowadays this is on decrease in favour of the production of ferrosilicon for the steelmaking industry. Industrial quartzite are marketed in various grades, containing 97–99% SiO_2, 0.5–2.2% Al_2O_3 + TiO_2, and 0.1–0.8% Fe_2O_3, with grain size usually above 40 mm (up to 250 mm). Suitability for the production of refractory materials is dependent on the susceptibility of quartz to transform into tridimite, which is very desirable as this quartz polymorph do not substantially change its volume in high temperatures (Galos 1999).

The only domestic supplier of industrial quartzite has been Bukowa Góra mine in Łączna (Świętokrzyskie Mts.). In the years 1975–2009 the plant was operated by KiZPK Bukowa Góra, and afterwards by German company PSS SE (in January 2011 the new owner changed the plant name to PCC Silicium). The obtained quartzite sandstones have been simply processed in course of crushing, classification and washing, in order to remove clay minerals/ /contaminations. The plant has delivered industrial quartzite in various grades (KpSi99, KpSi98, KpSi97 – the number corresponds to minimum content of SiO_2) and fractions (40–100 mm and 100–300 mm). The best quality products are characterized by content of SiO_2 above 99%, below 0.3% of Al_2O_3 and density after firing between 2.35 and 2.50 g/cm^3. Their production, ranging from 100,000 to 300,000 tpy in the 1990s, in recent years has significantly diminished (Tab. 32). It has been a result of substantial decrease in domestic demand of major consumers (the ferroalloys and refractory industries), coupled with the competition from Ukrainian quartzite.

The highest quality quartzite has been traditionally imported. The supplies have been predominantly originated from Owrucz mine in Ukraine, the raw material of which exhibits very high susceptibility to transform into tridimite. Additionally, in 2008 some deliveries of quartzite (17,000 t) came from Germany. Before 2000 the total importation did not exceed 10,000 tpy, while in subsequent years it fluctuated widely from 14,000 tpy in 2009 to 144,000 tpy in the last two years (Tab. 33). On the other hand, some amounts of industrial quartzite from Bukowa Góra has been irregularly exported to Slovakia (3,000–121,000 tpy in the years 1993–2005, and 8,000–42,000 tpy since 2010) for the production of ferroalloys at Oravske Ferozliatinarske Zavody.

The average unit values of industrial quartzite importation from Ukraine generally maintained at the level 30–40 PLN/t (Tab. 34), with growth to 54 PLN/t in 2012 (Tab. 35). These values were slightly lower than the average prices of the raw material exported to Slovakia (60–90 PLN/t in the years 2010–2012).

Over the last twenty years the consumption of quartzite in Poland has been considerably reduced. In the 1990s it ranged 100,000–200,000 tpy, whereas in the last decade it widely fluctuated at much lower level, occasionally decreasing to ca. 35,000 t (Tab. 32). The production of refractory materials has been of minor importance in the total domestic consumption of industrial quartzite. It is estimated that this sector has utilized less than 1% of industrial quartzite consumed in Poland, whereas overwhelming majority has gone to Łaziska Smelter for the manufacture of ferrosilicon. As a result of technological changes in the steelmaking industry the demand for siliceous refractories has been considerably reduced (from 150,000–200,000 in the 1980s to only 5,000–31,000 tpy in recent years) in favour of alkaline refractories (Tab. 36). The only supplier of siliceous refractories in Poland has been Chrzanów Refractory Plant (in ZM Ropczyce Capital Group). The company has provided shaped products, as well as mixes and mortars, applied primarily for the lining coke ovens and glass-furnaces. It is estimated that recent consumption of industrial quartzite of both domestic and foreign origin in that plant has oscillated around 1,000 tpy. The majority of the raw material utilized has originated from Bukowa Góra.

Domestic demand for quartzite is not expected to considerably increase in the following years as the forecast for the siliceous refractory materials are not optimistic. The periodical increases in the consumption might be correlated mostly with the coke oven batteries restoration and modernization. Due to the lack of domestic sources of the highest quality refractory quartzite, the importation of the raw material from Ukraine will be maintained. Sufficiency of domestic resources of Bukowa Góra deposit is difficult to precisely evaluate. It should be mentioned that because of low demand for industrial quartzite, the deposit has been reclassified into the group of crushed and dimension stone and the mine' sales has been dominated by crushed aggregates (recently 0.5–1.6 Mtpy). Taking into account the current output, it is estimated that Bukowa Góra will be operating for at least 10 years. The resources of other quartzite deposits (quartzite sandstone) that occur in the Świętokrzyskie Mts. near Łagów (Góra Skała, Wojtkowa Góra I and II) and Starachowice (Doły Biskupie) amounted to 4,438,000 tons (as of 31 December 2012, Mineral Resources Datafile… 2013). The highest quality quartzite of Bolesławiec type are of historical importance. The resources of 14 deposits occuring in the Lower Silesia amounted to 2,442,000 tons, but resumption of the mining activity there probably will be not possible. This results from the the fact that the resources left in 11 abandoned deposits are too small to be mined in a way that would be economicall profitable, the quality of the raw material of Milków deposit is poor, while in Kowalskie deposit' overburden fertile soils occur.

Other siliceous rock applied in the refractory industry has been quartz-schist from Jegłowa deposit in the Lower Siesia. It was extracted for over 150 years and initially utilized in the form of shaped lining elements. Since the 1970s quartz-schist has been processed into silica mortars and mixes for the refractory industry in three grades of particle sizes: <0.5, 0.5–1.0 and 1–2 mm, containing more than 88% SiO_2, with minimal refractoriness 1,670°C. Until 1998 the deposit was operated by Dolnośląskie Zakłady Magnezytowe in Świdnica, while in the years 1998–2008 – by PPHU Kwarcyt Danuta Kwiatkowska. The recent owner of the deposit was Quartz System Kopalnie. The production of refractory commodities gradually diminished, from 26,600 tpy in 1990 to 3,000 in 1998, and eventually was ceased in 1999 (Tab. 32). In 2000 the mine was reopened but the output of refractory mortars and mixes, which varied in the range of 2,000–10,000 tpy by 2006, in the following years dropped even below 1,000 tpy and finally was again suspended. Until the mid-1900s the demand for quartz-schist in the refractory industry hadn't exceeded 10,000 tpy, while in recent years it was reduced to below 1,000 tpy. Due to low grade of the raw material left in the deposit as well as decreasing production of siliceous refractory materials, the vast majority of the run-off-mine has been applied in the form of split tiles as a building stone. There is very slight chance to restart the production of refractory grades.

1.8. Dolomites for the refractory industry

The basic raw materials for the production of dead burned (sintered) dolomite for the refractory industry in Poland are Triassic dolomites and – to a limited extent – also some their Devonian varieties, from the Silesia-Kraków region. Although the domestic resources of dolomite and dolomitic marbles are huge, the quality of other varieties of dolomites – apart from the mentioned above – fails to ensure proper quality of dead burned dolomite either due to lack of sinterability in the firing process or high content of Fe_2O_3. In recent years the significance of various grades of raw materials for sintered dolomite manufacturing has changed significantly, i.e.: the use of high-ferric dolomites (the so-called ankeritic species) has been considerably reduced in favour of pure dolomite varieties. The presence of low-melting phases of ferrite and aluminate in sintered dolomite adversely influences the resistance of dolomite products for corrosion at oxygen converters and steelmaking tubs. Thus, in modern applications of these products the content of some impurities (including Fe_2O_3) should be reduced to the lowest possible level, despite the fact that they explicitly facilitate sintering in the process of dolomite clinker production (Wyszomirski and Galos 2007). Raw dolomite currently utilized in the refractory industry must be characterized by low contents of SiO_2 and Al_2O_3, as well as insignificant amounts of Fe_2O_3 and, of course, the highest possible content of MgO. This is confirmed by the former BN-86/6761-16 standard (Tab. 37), specifying the quality requirements for dolomites utilized as fluxes in the metallurgy and the refractory industry (for the production of sintered dolomite).

The above-mentioned standard has specified six grades of raw dolomite for metallurgy and the refractory industry, three of which can be suitable for the production of relevant varieties of dead burned dolomite, i.e.:

- the highest quality DK grade with min. 19% MgO, max. 1.0% SiO_2 and max. 1.3% Fe_2O_3 for the production of the best dead burned dolomite of DKS grade, which is utilized in the refractory industry for manufacturing of dolomitic refractory bricks;
- DM1 and DM2 grades containing respectively min. 17.5% and 16.0% MgO, max. 2.0% and 2.8% SiO_2, and max. 3.0% and 6.5% Fe_2O_3 (features typical for ankeritic dolomites), tailored for dead burned dolomite manufacturing in DMS1 and DMS2 varieties, which are applied as components of dolomitic masses of inferior quality.

In Poland, despite the abundance of dolomitic rocks deposits, only dolomites from the Silesia-Kraków region are suitable for the production of dead burned dolomite of refractory grade. A few deposits of Devonian dolomites of potential usefulness for this purpose are known in the Świętokrzyskie region, but they have not been utilized so far. In the Silesia-Kraków region there are basically Triassic dolomites represented by diplopora and ore-bearing varieties, and subordinately – also Devonian ones. Over the last 30 years the

Table 37

Major requirements for raw and dead burned dolomites utilized in the refractory industry
(acc. to BN-86/6761-16 and BN-75/6761-13 standards)

Tabela 37

Ważniejsze wymagania stawiane dolomitom surowym i prażonym dla przemysłu materiałów ogniotrwałych
(wg norm BN-86/6761-16 i BN-75/6761-13)

Parameter	Raw dolomite grades		
	DM1	DM2	DK
MgO [%, min.]	17.5	16.0	19.0
SiO_2 [%, max.]	2.0	2.8	1.0
Al_2O_3 [%, max.]	0.5	1.0	0.7
Fe_2O_3 [%, max.]	3.0	6.5	1.3
	Dead burned dolomite grades		
	DMS1	DMS2	DKS
LOI [%, max.]	2.5	2.5	1.0
MgO [%, min.]	30.0	27.0	34.0
SiO_2 [%, max.]	3.5	5.3	2.5
$Al_2O_3 + Fe_2O_3$ [%, max.]	7.0	12.0	4.5
including Fe_2O_3 [%, max.]	6.0	10.5	3.5
Apparent density [g/cm^3, min.]	–	–	2.9
Open porosity [%, max.]	–	–	10.0

production of sintered dolomite was sourced from Triassic dolomites occurring in the following deposits: Brudzowice, Żelatowa, Gródek, Bobrowniki-Blachówka, and Ząbkowice Będzińskie. However, the best DK grade was obtained only from Brudzowice and Żelatowa deposits. Since a couple of years the only source of the raw material for this production has remained Brudzowice. Dolomites from the remaining above-mentioned deposits have been utilized in manufacturing DM1 and DM2 grades. Gródek and Bobrowniki–Blachówka deposits were abandoned in the mid-1990s, while dolomite extracted from Żelatowa and Ząbkowice Będzińskie deposits has been utilized mainly for the production of aggregates (Galos 1999; Minerals Yearbook... 2014). As a result, raw dolomites suitable for dead burned dolomite manufacturing have been obtained only at Brudzowice mine belonging to Górnicze Zakłady Dolomitowe of Siewierz. Both Triassic and Devonian dolomites have been extracted there. These varieties differ extremely from each other in terms of lithology and structure, and – to a lesser extent – in chemical composition, which has fundamental influence on suitability for the refractory industry. Triassic dolomites are characterized by usually fine-crystalline structure, grey-yellow colour, varying compactness, open porosity

2–20%, bulk density 2.4–2.7 g/cm^3, the content of MgO between 19 and 20%, and generally heterogenous chemical composition, in particular in terms of Fe_2O_3 and SiO_2 contents. Devonian dolomites are in turn usually coarsely crystalline, ashen and grey in colour, very compact, with porosity 1–4% and bulk density 2.7–2.8 g/cm^3. They are characterized by high purity and stability of chemical composition, with average content 20–21% MgO and very low content of SiO_2 and Fe_2O_3 (Galos 1999; Niesyt et al. 2012).

The Brudzowice deposit has been recently the major documented source of dolomite for the refractory industry. However, dead burned dolomite has not been manufactured on site. Dolomitic stone of adequate quality has been transported to roasting plant of ArcellorMittal Refractories of Kraków and to PPRS Chemokor Dąbrowa Górnicza of the former Katowice Steelworks (currently ArcellorMittal Poland), where appropriate dead burned dolomite grades have been obtained, i.e. DKS, DMS1, DMS2 (Minerals Yearbook... 2014). Extracted

Table 38

Dead burned dolomite statistics in Poland [‘000 t]

Tabela 38

Gospodarka dolomitem prażonym w Polsce [tys. t]

Item/Year	1990	1991	1992	1993	1994	1995	1996	1997
Production	264.2	266.5	250.3	201.6	221.7	234.1	202.3	198.4
Import	–	–	1.2	3.6	4.0	1.4	1.3	0.0
Export	–	–	0.1	0.3	0.2	0.0	0.0	0.0
Consumption	264.2	266.5	251.4	204.9	225.5	235.5	203.6	198.4

Year	1998	1999	2000	2001	2002	2003	2004	2005
Production	157.7	147.6	174.4	160.6	145.8	114.1	151.5	127.7
Import	1.1	0.1	0.1	0.1	0.2	0.6	0.8	8.7
Export	0.2	1.7	3.4	0.1	0.2	0.1	2.0	0.1
Consumption	158.6	146.0	171.1	160.6	145.8	114.6	150.3	136.6

Year	2006	2007	2008	2009	2010	2011	2012
Production	140.4	182.9	127.4	84.4	93.5	84.6	67.3
Import	0.9	0.6	0.6	0.9	1.9	4.8	7.0
Export	0.0	0.0	0.0	0.2	0.3	0.4	6.6
Consumption	141.3	129.5	128.0	85.1	95.1	89.0	67.7

Source: Central Statistical Office (GUS)

Triassic dolomite is characterized by good sinterability. After the exhaustion of its reserves, high purity Devonian dolomite of relatively worse sinterability and lower hydration resistance, could be utilized (Niesyt et al. 2012). However, the production of sintered dolomite from such a raw material will undoubtedly require a two-step sintering process with an intermediate stage of briquetting.

The total volume of dead burned dolomite of all grades manufactured in Poland in the 1980s exceeded 400,000 tpy, 10% of which was DKS grade for dolomite-tar products, while the vast majority were DMS1 and DMS2 grades for low quality dolomitic refractory masses (Galos 1999). In subsequent years the systematic decrease in DMS1 and DMS2 utilization with small reduction of DKS grade consumption resulted in dramatic drop in the production of dead burned dolomite in Poland, to 150,000–170,000 tpy around 2000 and less than 100,000 tpy from 2009 onwards (Tab. 38). Trade in this case has been of marginal importance (Minerals Yearbook... 2014, Tab. 39).

Table 39

Quantity and average unit values of dead burned dolomite importation to Poland in 2012, by country

Tabela 39

Kierunki i średnie wartości jednostkowe importu dolomitu prażonego do Polski w 2012 r.

Country	Quantity [‘000 t]	Unit value [PLN/t]
Total imports, including:	**6.9**	**381**
Germany	0.8	214
Slovakia	5.1	252
United Kingdom	0.8	987
Italy	0.2	1,369

Source: Central Statistical Office (GUS)

Future demand for dead burned dolomite for the refractory industry will depend on dolomite refractory masses consumption in electric arc furnaces of steel mills as well as the use of dolomite and dolomite-tar bricks in basic oxygen converters of smelters in Kraków and Dąbrowa Górnicza. In each of these applications a tendency to replace dead burned dolomite of domestic origin by higher quality and more durable products made from imported sintered magnesite, has been observed. Therefore, in coming years it is anticipated that the production of dead burned dolomite will not exceed 120,000 tpy and most likely will be further reduced, even to 50,000–60,000 tpy.

Another factor contributing to this scenario will be the depletion of resources of these varieties of Triassic dolomite from Brudzowice deposit that meet the requirements for the production of DK grade, simultaneously showing good sinterability. To be able to continue DKS dead burned dolomite manufacturing it will be necessary to implement two-step sintering process with intermediate stage of briquetting. This is a prerequisite to obtain high quality dead burned dolomite of DKS grade from pure Devonian dolomite from Brudzowice deposit, which – without additional treatment – shows poorer sinterability (i.e. after one-step sintering process). Another alternative could be the utilization of dolomites from other deposits, i.e. Triassic variety from Ząbkowice Będzińskie or Devonian one from Winna – although they exhibit increased content of SiO_2, i.e. above 1 or even 2 wt. % (Niesyt et al. 2012).

At the end of 2012 economic resources of Brudzowice deposit were around 33.3 Mt. Anticipated economic resources of three neighbouring deposits of Devonian dolomite located in the vicinity of Chruszczobród, having similar properties to Devonian dolomite from Brudzowice deposit, amounted to around 110 Mt (Mineral Resources Datafile... 2013). In the Świętokrzyskie region there are also significant resources of Devonian dolomites (around 470 Mt, including over 300 Mt in the western part of Opatów county), although they have been formally documented as suitable for the production of crushed aggregates. According to preliminary examinations (Niesyt et al. 2012), they could be also considered as a potential source of dolomites for dead burned dolomite manufacturing. Virtually there are neither undeveloped deposits of Triassic dolomites for the production of good quality dead burned dolomite nor any prognostic areas of occurrence of Triassic or Devonian dolomites useful for this purpose.

2. Raw materials exclusively of foreign origin

2.1. Zirconium raw materials

Zirconium (Zr) in metallic form is utilized to a limited scale (in cores of nuclear reactors, a component of some alloys). Their minerals find definitely more applications, i.e. most of all zircon $ZrSiO_4$ (foundry, refractories, ceramics, abrasives), and – to a lesser extent – baddeleyite ZrO_2 and its synthetic equivalent – cubic zirconia ZrO_2. The fundamental importance as a source of zirconium raw materials have the placer deposits of heavy minerals, including Zr-bearing sands, while spent molding sand and scrapped zirconia refractories are of minor importance.

The main commercial zirconium raw materials are: zircon concentrates, including standard (min. 65% ZrO_2), intermediate (65.5–66% ZrO_2, 0.06–0.1% Fe_2O_3) and premium grade (min. 66% ZrO_2, max. 0.05% Fe_2O_3), zircon flours (normal grades 45–75 μm for foundry and ceramics, and micronized <20 μm for ceramic glazes), baddeleyite concentrates (96–98% ZrO_2, below 100 mesh, and min. 99% ZrO_2, below 325 mesh), as well as synthetic zirconium oxide (zirconia) (Bilans gospodarki… 2014).

In Poland, some negligible amounts of zircon could be obtained in course of processing of quartz sand from Osiecznica deposit. However, it has not been recovered so far. Zircon occurs also as a component of heavy fraction (5–9%) of sand from the Baltic sea beach. Its potential source are also Oderbank Plateau and Słupsk shoal may (estimated resources of around 2,000 t $ZrSiO_4$).

The demand for zirconium raw materials in Poland has been covered by imports, basically of zircon concentrates and flours. Since 1990, these deliveries fluctuated in a wide range, which resulted from – on one hand – variations in the needs of domestic recipients, and substantial volatilty in prices of these commodities – on the other. During this period the importation of zircon concentrates and flours exceeded 2,000 tpy only in 1990 and 2001, while since 2005 it has ranged from 360 to 870 tpy (Tab. 40).

An increase in imports recorded until recently, that resulted from rapid growth of demand for zircon flour in the domestic ceramic tile industry, has been reduced due to high prices of this commodity (Tabs. 40, 43). Currently, zircon concentrates have been imported in the total amount up to 50 tpy, basically from Ukraine and South Africa. The remainder has been constituted by zircon flour, imported mostly from Germany, France, the Netherlands, Spain, South Africa, Italy, Australia, and the United Kingdom (Tab. 41). The significance of zircon

Table 40

Zircon concentrates staistics in Poland [t]

Tabela 40

Gospodarka koncentratami cyrkonu w Polsce [t]

Item/Year	1990	1991	1992	1993	1994	1995	1996	1997
Imports	2,630	1,195	1,883	1,861	734	572	1,142	1,455
Exports	–	–	114	48	–	–	–	6
Apparent consumption	2,630	1,195	1,769	1,813	734	752	1,142	1,449

Item/Year	1998	1999	2000	2001	2002	2003	2004	2005
Imports	1,024	956	1,790	2,240	1,207	1,123	1,084	868
Exports	22	1	–	–	0	–	–	–
Apparent consumption	1,004	955	1,790	2,240	1,207	1,123	1,084	868

Item/Year	2006	2007	2008	2009	2010	2011	2012
Imports	839	542	844	364	624	487	670
Exports	28	2	3	1	101	3	17
Apparent consumption	811	540	81	33	53	4	6

Source: Central Statistical Office (GUS)

flour of Australian origin has been on decrease in favour of flour obtained from zircon concentrates coming from Germany, the Netherlands and other Western European countries (Tab. 42). Since 2006, small re-exports of zircon concentrates and flours, mainly to the Czech Republic and Lithuania, have been recorded on regular basis (Tab. 40). In 2010, there were significant re-exports of zircon flour to Russia and Belarus, while in 2012 – smaller amounts were sold to Ukraine and Hungary.

The unit values of zircon concentrates and flour importation to Poland in recent years (with the exception of 2010) have been systematically rising (Tabs. 43, 44), generally in accordance with trends in the world prices of these commodities. This has referred to zircon concentrates of unit value of 6,000–8,000 PLN/t, as well as to zircon flours of unit value usually exceeding 12,000 PLN/t.

Zircon raw materials has been imported traditionally for the needs of the foundry and refractory industries. Over the years the latter one has been their most important consumer. In 1977 the production of fused corundum-zirconium goods, mainly for the use in glass kilns, was commenced at Górka plant in Trzebinia. Since the 1990s another company – Vesuvius Skawina Refractories – has become the most important consumer of zircon concentrates

Table 41

Zirconium flour and concentrates importation to Poland, by country [t]

Tabela 41

Kierunki importu mączek i koncentratów cyrkonu do Polski [t]

Country/Year	1990	1991	1992	1993	1994	1995	1996	1997
Total imports	**2,630**	**1,195**	**1,883**	**1,861**	**734**	**572**	**1,142**	**1,455**
Australia	–	–	225	–	–	–	615	559
France	–	–	–	–	–	–	–	24
Germany	670	367	330	760	362	496	312	253
Italy	–	–	2	–	–	–	24	187
Netherlands	–	–	70	165	165	58	155	201
South Africa	–	–	148	–	–	–	25	28
Spain	–	–	–	–	–	–	–	–
Switzerland	1,474	828	1,108	811	184	14	–	–
Ukraine	–	–	–	–	–	–	–	179
United Kingdom	485	–	–	125	0	4	–	–
USA	–	–	–	–	–	–	–	–
Others	–	–	–	–	23	–	11	3

Country/Year	1998	1999	2000	2001	2002	2003	2004	2005
Total imports	**1,024**	**956**	**1,790**	**2,240**	**1,207**	**1,123**	**1,084**	**868**
Australia	358	234	221	74	152	86	62	32
France	–	7	12	9	12	11	10	12
Germany	47	91	303	684	186	488	265	400
Italy	158	141	330	272	18	4	2	–
Netherlands	270	290	524	790	409	50	2	2
South Africa	43	118	268	92	145	172	223	90
Spain	–	–	4	89	47	1	1	144
Switzerland	–	–	–	–	–	–	–	–
Ukraine	145	75	69	50	70	202	183	86
United Kingdom	–	–	48	168	144	108	336	–
USA	1	0	10	0	0	1	–	96
Others	2	–	1	12	24	–	–	6

Table 41 cont.

Tabela 41 cd.

Country/Year	2006	2007	2008	2009	2010	2011	2012
Total imports	**839**	**542**	**844**	**364**	**624**	**478**	**670**
Australia	19	19	35	31	20	32	23
France	8	8	5	48	132	42	61
Germany	419	84	56	18	150	229	115
Italy	–	1	14	3	3	24	24
Netherlands	50	22	85	17	58	124	116
South Africa	65	192	185	58	29	24	27
Spain	72	60	97	94	148	2	287
Switzerland	–	–	–	–	–	–	–
Ukraine	206	148	315	21	8	–	1
USA	–	2	40	–	25	0	11
United Kingdom	–	3	12	62	24	0	0
Others	–	3	0	12	27	3	17

Source: Central Statistical Office (GUS)

Table 42

The structure of zircon flour and concentrates importation to Poland in 1992, 2002 and 2011 [%]

Tabela 42

Struktura importu mączek i koncentratów cyrkonu do Polski w latach 1992, 2002 i 2011 [%]

Country/Year	1992	2002	2011
Australia[1]	70.8	12.6	6.7
Netherlands	3.7	33.9	25.9
Germany	17.5	15.4	47.9
South Africa	7.9	12.0	5.0
Ukraine	–	5.8	–
United Kingdom	–	11.9	–
Others	0.1	8.5	14.5

[1] In 1992 together with re-exports from Switzerland.

Table 43

Average unit values of zircon flours and concentrates importation to Poland from selected countries [PLN/t]

Tabela 43

Średnie wartości jednostkowe importu mączek i koncentratów cyrkonu do Polski
z wybranych kierunków [zł/t]

Country/Year	1992	1996	2000	2004	2005	2006	2007	2008	2009	2010	2011	2012
Average value	521	2,288	2,136	2,866	3,113	3,601	3,301	3,158	7,081	5,361	7,716	9,272
Australia	400	2,316	1,773	3,537	4,417	5,665	5,752	5,050	7,447	7,540	12,306	16,481
Netherlands	574	2,003	2,092	14,999	13,687	3,350	3,283	2,755	3,840	3,231	6,030	8,883
Germany	708	2,332	1,940	2,761	2,825	3,626	3,443	2,696	3,747	5,296	6,872	8,177
South Africa	585	2,056	2,182	2,472	2,780	3,145	2,983	2,585	7,397	3,312	8,553	7,300
Ukraine	–	–	1,788	2,427	3,141	3,482	2,722	2,412	3,263	3,043	–	8,573

Source: Central Statistical Office (GUS)

Table 44

Quantity and average unit values of zircon flour and concentrates importation to Poland in 2012

Tabela 44

Wielkości i średnie wartości jednostkowe importu mączek i koncentratów cyrkonu do Polski w 2012 r.

Country	Quantity [t]	Unit value [PLN/t]
Total imports	**670**	**9,272**
Spain	287	8,244
Netherlands	116	8,883
Germany	115	8,177
France	61	13,607
South Africa	27	7,300
Italy	24	8,562
Australia	23	16,481
USA	11	22,210
Ukraine	1	8,573

Source: Central Statistical Office (GUS)

in the refractory industry, as it started the production of similar fused products, as well as corundum-zirconium concretes and mortars (Galos 1999). Recently, in turn, there have been attempts to obtain magnesia refractory products with the addition of several percent of ZrO_2, and even larger – 20% addition of calcium zirconate, as well as trials of the manufacture of dolomite-zircon products. The domestic refractory industry has also utilized small amounts of synthetic zirconia, utilized in the production of sliding closure elements of steel ladles (Wyszomirski and Galos 2007). The consumption of zircon concentrates in this branch approached around 300 tpy in the 1990s (Galos 1999), with a distinct reduction to just a few dozen tons recently, which has partially resulted from re-using of scrapped zirconium-bearing refractories.

Since the mid-1990s the application of zircon flours as opacifiers of ceramic glazes, especially in the ceramic tiles and sanitaryware industries, has been developed. This has been in accordance with general global trends (Wyszomirski and Galos 2007). The consumption of zircon flours in the ceramic tiles and sanitaryware industries reached its maximum level of over 2,000 tpy in 1990 and 2001 (Tab. 40). In the last decade, however, the demand has been significantly reduced due to persistenly high prices of the flour. Despite this, the industry has remained the primary consumer of zirconium raw materials in Poland (over 90% of the total consumption), the probable demand for which has recently amounted to ca. 400–600 tpy.

The marginal users of zircon and synthetic zirconia have been also manufacturers of ceramic dyes and abrasives, as well as the foundry industry, consuming exclusively zircon concentrates.

2.2. Andalusite – kyanite – sillimanite

Andalusite, kyanite and sillimanite are three minerals of identical chemical composition ($Al_2O_3 \cdot SiO_2$) that differ from each other in terms of structure (Al^{+3} cations occurs in different coordinations). Minerals belonging to this group occur in metamorphic rocks (schists, gneisses, quartzites, corundum-sillimanite rocks) and also as a component of heavy fraction of clastic deposits. When roasted, starting from 1,315°C (kyanite) up to 1,549°C (sillimanite) they form a mixture of mullite and quartz glaze, while at 1,810°C – corundum and quartz glaze. This feature constitutes their suitability for the production of high-alumina refractories.

Concentrates of sillimanite, andalusite and kyanite with chemical composition similar to mullite (72% Al_2O_3, 28% SiO_2) are commercial products traded internationally. Andalusite concentrates contain usually 55–61% Al_2O_3, 37–42% SiO_2 and 0.6–1.1% Fe_2O_3, and are characterized by grain size below 3–4 mm, kyanite concentrates contain 54–61% Al_2O_3, 37–44% SiO_2 and 0.1–0.9% Fe_2O_3, while sillimanite concentrates – 59–61% Al_2O_3, around 37% SiO_2 and up to 0.5% Fe_2O_3 (Bilans gospodarki… 2014).

Since the beginning of the 1990s domestic demand for andalusite raw materials has been covered by importation of their concentrates. The volume of these deliveries has varied depending on the condition of domestic steelmaking, which is a major recipient of andalusite refractories, as well as on international prices of these commodities. Therefore, their imports have varied widely from 7,800 to 20,600 tpy (Tab. 45). Deliveries of andalusite concentrates have originated from South Africa (partly through European brokers, mainly German, and sometimes Czech, Dutch or Swedish) and France (Tab. 46). Since 2009 andalusite concentrates have been purchased also from a new Peruvian mine. Over the past twenty years the share of South Africa in the total supplies was diminishing, down to 56% in 2012, while that of France – remained at around 20%, with Peru emerging as a new important supplier (Tab. 47). Occasionally, some small quantities of kyanite concentrates have been also imported from the USA, and sometimes from India and China (Tab. 46). Re-exports of these raw materials have been negligible and irregular (Tab. 45).

Table 45

Andalusite concentrates and related raw materials statistics in Poland [t]

Tabela 45

Gospodarka koncentratami andaluzytowymi i pokrewnymi w Polsce [t]

Item/Year	1992	1993	1994	1995	1996	1997	1998
Imports	9,339	10,324	13,297	19,827	16,461	15,643	14,519
Exports	0	5	5	41	36	17	2
Apparent consumption	9,339	10,319	13,292	19,786	16,425	15,626	14,517

Item/Year	1999	2000	2001	2002	2003	2004	2005
Imports	7,760	8,697	11,872	16,182	17,746	14,749	10,038
Exports	2	–	–	–	–	–	2
Apparent consumption	7,758	8,697	11,872	16,182	17,746	14,749	10,036

Item/Year	2006	2007	2008	2009	2010	2011	2012
Imports	20,604	24,433	17,683	7,764	17,979	13,579	17,384
Exports	8	83	35	1	–	–	0
Apparent consumption	20,596	24,350	17,648	7,763	17,979	13,579	17,384

Source: Central Statistical Office (GUS)

In recent years the average unit values of importation of andalusite concentrates and related raw materials have fluctuated between 940 and 1,475 PLN/t (Tabs. 48, 49). Prices of French concentrates have been usually slightly lower than these of South African or – recently – Peruvian origin. Pronounced sharp rise in these prices was noted in 2009–2010, with a slight reduction in 2011–2012. Except the last two years, prices of kyanite concentrates of American origin have been significantly higher than andalusite ones. The concentrates of kyanite temporarily imported from India have been the cheapest ones.

Table 46

Imports of andalusite concentrates and related raw materials to Poland, by country [t]

Tabela 46

Kierunki importu koncentratów andaluzytowych i pokrewnych do Polski [t]

Country/Year	1992	1993	1994	1995	1996	1997	1998
Total imports	**9,339**	**10,324**	**13,297**	**19,827**	**16,461**	**15,643**	**14,519**
China	–	–	–	–	–	–	–
Czech Republic	–	110	727	2,681	–	–	–
France	1,596	7,380	7,477	2,166	3,934	3,137	2,060
Netherlands	–	–	953	–	–	–	–
India	–	–	–	–	–	–	–
Germany	1,735	2,834	1,260	2,917	63	24	12
Peru	–	–	–	–	–	–	–
South Africa	6,008	–	2,837	12,010	12,464	12,445	12,423
Sweden	–	–	–	–	–	–	–
USA	–	–	–	–	–	–	–
Others	–	–	43	53	–	1	24

Country/Year	1999	2000	2001	2002	2003	2004	2005
Total imports	**7,760**	**8,697**	**11,872**	**16,182**	**17,746**	**14,749**	**10,038**
China	–	–	23	–	–	–	–
Czech Republic	–	–	–	–	–	230	75
France	762	1,356	1,560	4,210	8,138	5,170	1,697
Netherlands	–	–	0	–	–	49	–
India	–	–	–	–	–	–	–
Germany	–	7	39	39	39	208	134
Peru	–	–	–	–	–	–	–
South Africa	6,987	7,293	10,053	11,820	9,544	8,818	8,041
Sweden	–	–	135	24	–	42	19
USA	–	–	–	–	–	232	72
Others	11	41	62	85	25	–	–

Table 46 cont.

Tabela 46 cd.

Country/Year	2006	2007	2008	2009	2010	2011	2012
Total imports	**20,604**	**24,433**	**17,683**	**7,764**	**17,979**	**13,579**	**17,384**
China	–	60	–	20	100	–	–
Czech Republic	–	–	–	–	–	–	–
France	11,231	12,203	10,132	2,810	7,289	3,386	3,495
Netherlands	3	24	24	–	170	–	–
India	–	–	50	225	450	–	–
Germany	34	215	211	39	597	345	527
Peru	–	–	–	20	1,582	2,800	3,850
South Africa	9,208	1,1863	7,195	4,444	7,746	6,621	8,693
Sweden	–	–	–	–	–	–	–
USA	35	22	15	124	20	329	324
Others	93	46	56	82	25	98	195

Source: Central Statistical Office (GUS)

Table 47

Structure of imports of andalusite concentrates and related raw materials to Poland in 1992, 2002 and 2012 [%]

Tabela 47

Struktura importu koncentratów andaluzytowych i pokrewnych do Polski w latach 1992, 2002 i 2012 [%]

Country/Year	1992	2002	2012
France	17.0	26.0	20.1
Peru	–	–	22.1
South Africa	83.0	74.0	55.9
USA	–	–	1.9

The vast majority (over 95%) of andalusite concentrates and marginal quantities of kyanite concentrates have been utilized in Poland for the production of high-alumina refractory materials, as these raw materials are able to form high-refractory mullite phase ($3Al_2O_3.2SiO_2$) at high temperatures. The mullite phase is characterized by high resistance to chemical and physical corrosion. Its other essential features are low coefficient of thermal expansion and relatively high thermal conductivity that determine high immunity to thermal shock, as well as good mechanical strength, excellent resistivity to dross influence and

Table 48

Average unit values of andalusite concentrates and related raw materials importation to Poland from selected countries [PLN/t]

Tabela 48

Średnie wartości jednostkowe importu koncentratów andaluzytowych i pokrewnych do Polski z wybranych kierunków [zł/t]

Country/Year	1992	1996	2000	2004	2005	2006	2007	2008	2009	2010	2011	2012
Average value	**350**	**804**	**957**	**1,174**	**1,062**	**942**	**968**	**970**	**1,334**	**1,319**	**1,475**	**1,451**
France	384	815	943	910	1,090	841	891	848	1,199	1,236	1,461	1,458
Germany	430	918	1,836	2,527	1,112	1,273	1,056	1,097	1,631	1,353	1,713	1,581
Peru	–	–	–	–	–	–	–	–	1,190	1,297	1,472	1,604
South Africa	317	800	956	1,124	1,051	1,061	1,043	1,132	1,455	1,404	1,474	1,379
USA	–	5,423	1,390	1,521	1,102	1,094	1,005	957	1,399	1,677	1,287	1,349

Source: Central Statistical Office (GUS)

Table 49

Quantities and average unit values of andalusite concentrates and related raw materials importation to Poland in 2012

Tabela 49

Kierunki i średnie wartości jednostkowe importu koncentratów andaluzytowych i pokrewnych do Polski w 2012 r.

Country	Quantity [t]	Unit value [PLN/t]
Total imports	**17,384**	**1,451**
France	3,495	1,458
Germany	527	1,581
Peru	3,850	1,604
South Africa	8,693	1,379
USA	324	1,349

deformation under load, low open porosity, and increased resistivity to reducing conditions and volatile alkalies (Galos 1999).

The utilization of andalusite and related raw materials in the domestic refractory industry was commenced in 1992 in Skawina, and after that they have been implemented in other plants supplying high-alumina refractories, e.g. in Kraków, Żarów, Częstochowa, Gliwice, and Trzebinia. Until the early 1990s the main raw material for the production of high-alumina refractory products in Poland had been the so-called high-alumina fired feedstock (grogs) manufactured at ZSO Górka in Trzebinia (Galos 1999), while since the mid-1990s andalusite or kyanite concentrates, as well as calcined bauxites, has started to be of primary importance (Tab. 50). Currently the production of refractories on the basis of these raw materials have been carried out at Vesuvius Skawina Refractory Materials, and – to a lesser extent – also at Arcellormittal Refractories of Kraków and PCO Żarów.

Table 50

The production of high-alumina refractories in Poland [‘000 t]

Tabela 50

Produkcja wysokoglinowych materiałów ogniotrwałych w Polsce [tys. t]

Year	1990	1991	1992	1993	1994	1995	1996	1997
Production	101.6	65.2	60.1	48.0	42.5	49.6	51.7	41.4

Year	1998	1999	2000	2001	2002	2003	2004	2005
Production	65.3	51.5	21.9	24.2	31.3	37.2	38.1	37.1

Year	2006	2007	2008	2009	2010	2011	2012
Production	40.2	45.7	40.0	23.1	31.9	36.4	24.8

Source: Central Statistical Office (GUS)

High-alumina bricks and monolithic products manufactured with the use of andalusite raw materials have been traditionally consumed in the steelmaking (blast furnaces, vats, continuous steel casting) and glassmaking (glass melting vats, glass furnaces). They have been basically applied as a lining of electric furnaces for non-ferrous metals alloys manufacturing. In the rotary cement kilns these products have been used in introductory and final zones. They have been also utilized in tunnel furnaces of the ceramic industry of very high working temperature, some heating boilers, and in the petrochemical industry as well (Galos 1999).

The production of high-alumina refractories has stimulated the importation of andalusite and related raw materials (along with calcined bauxite of appropriate quality) to Poland. A variable prosperity of the domestic iron and steel industry, which has been a major consumer of these raw materials, has resulted in unstable demand for high-alumina refractories, and variable consumption volume of andalusite and related raw materials that has ranged between 7,000 and 20,000 tpy in recent years. The increases in demand were reported in 1995, 2002–2003, 2006–2008 and after 2010, while their deepest reductions – in 1999–2000 and in 2009 (Tab. 45).

2.3. Graphite

There are three basic varieties of graphite: large crystalline (lump), flake crystalline, and amorphous (cryptocrystalline). Graphite, due to its good thermal and electrical conductivity, resistance to chemicals and high temperatures, is suitable for the manufacture of refractory materials, as well as for foundries, brake friction linings and lubricants. In the refractory industry another required feature is high resistance to oxidation, which is characteristic particularly for flake varieties (Galos 1999, Suwak and Lipowska 2008). An important attribute is also high content of elemental carbon (usually >90%, sometimes even >98%), which enhances durability of refractory products.

Natural graphite is often subsituted by its synthetic variety, obtained by the graphitization of petroleum coke as well as other petroleum and coal derivatives. Synthetic graphite is utilized mainly in the refractory industry for the production of electrodes, in foundries, and for the production of graphite crucibles. However, substitution of natural graphite by synthetic one sometimes turns out to be uneconomic due to high cost of manufacturing of appropriate synthetic variety.

Table 51

Natural graphite statistics in Poland [t]

Tabela 51

Gospodarka grafitem naturalnym w Polsce [t]

Item/Year	1990	1991	1992	1993	1994	1995	1996	1997
Imports	1,738	632	5,343	3,364	1,433	1,948	2,360	2,187
Exports	–	–	4,079	902	35	12	59	11
Apparent consumption	1,738	632	1,264	2,462	1,398	1,936	2,301	2,176

Item/Year	1998	1999	2000	2001	2002	2003	2004	2005
Imports	3,021	2,586	3,127	2,856	2,700	3,328	3,040	3,038
Exports	7	11	19	37	3	2	2	4
Apparent consumption	3,014	2,575	3,108	2,819	2,697	3,326	3,038	3,034

Item/Year	2006	2007	2008	2009	2010	2011	2012
Imports	3,640	5,691	4,204	2,875	7,208	10,359	6,817
Exports	2	72	82	66	232	589	111
Apparent consumption	3,638	5,619	4,122	2,809	6,976	9,770	6,706

Source: Central Statistical Office (GUS)

Natural crystalline graphite is marketed in the form of flakes and lumps of different sizes, as well as dusts and powders.

The demand for natural graphite has been satisfied entirely by imports, which in the early 1990s generally did not exceed 2,000 tonnes per year (with the exception of 1992–1993, when its substantial quantities were re-exported). Between the mid-1990s and early 2000s the deliveries ranged from 2,000 to 3,300 tpy. Over subsequent years the substantial growth of imports, up to 10,000 tpy in 2011, was reported (Tab. 51). However, it should be pointed out that there were also years when significant decrease in the level of importation were reported (i.e. in 2009 and 2012). It was correlated with the situation in the steelmaking industry.

High volatility of natural graphite deliveries to Poland has been coupled with significant changes in their geographical structure. In the early 1990s the prominent suppliers were Austria, France, Germany and the United Kingdom, while in the following years graphite started to be imported also from Ukraine and non-European countries, such as Brazil, Canada, Madagascar, Mexico, Mozambique, and the USA (Tab. 52). Substantial imports of

Table 52

Natural graphite imports to Poland, by country [t]

Tabela 52

Kierunki importu grafitu naturalnego do Polski [t]

Country/Year	1990	1991	1992	1993	1994	1995	1996	1997
Total imports	**1,738**	**632**	**5,434**	**3,363**	**1,433**	**1,948**	**2,360**	**2,187**
Austria	1,154	384	598	575	447	587	712	478
Brazil	–	–	19	118	58	115	154	41
Canada	–	–	–	–	252	250	253	40
China	–	–	–	18	74	–	8	209
Czech Republic	–	20	–	8	4	138	208	235
France	128	73	18	41	–	–	–	–
Germany	45	80	46	78	31	100	257	431
Madagascar	–	–	25	139	160	160	160	109
Mexico	–	–	162	90	72	–	–	–
Mozambique	–	–	–	–	–	–	317	148
Russia	–	–	4,282	2,051	1	–	–	–
Ukraine	–	–	–	107	126	138	88	200
United Kingdom	111	45	151	32	29	64	50	20
USA	–	–	0	112	133	206	45	–
Others	300	30	133	–	46	190	108	276

Table 52 cont.

Tabela 52 cd.

Country/Year	1998	1999	2000	2001	2002	2003	2004	2005
Total imports	**3,021**	**2,586**	**3,727**	**2,856**	**2,700**	**3,328**	**3,040**	**3,038**
Austria	442	395	337	240	158	198	53	45
Brazil	260	100	400	200	200	–	–	–
Canada	800	100	660	560	–	–	–	–
China	537	810	1,014	912	1,650	2,377	2,016	1,825
Czech Republic	302	279	333	393	282	283	229	116
France	–	–	–	–	–	–	–	–
Germany	258	267	332	265	359	350	485	595
Madagascar	191	99	80	100	16	29	–	–
Mexico	–	–	–	–	–	–	–	–
Mozambique	38	469	–	–	–	–	–	–
Russia	–	–	–	–	–	–	–	–
Ukraine	144	21	40	10	3	12	69	231
United Kingdom	8	1	0	5	1	63	46	20
USA	–	–	–	–	–	–	–	–
Others	41	45	531	172	31	16	142	206

Country/Year	2006	2007	2008	2009	2010	2011	2012
Total imports	**3,640**	**5,691**	**4,204**	**2,875**	**7,208**	**10,359**	**6,817**
Austria	6	40	114	12	–	12	1
Brazil	–	–	–	–	–	–	–
Canada	–	–	–	–	–	–	–
China	2,164	4,135	2,522	2,376	4,016	6,815	3,508
Czech Republic	191	174	191	72	87	139	77
France	–	–	4	4	65	130	130
Germany	1,247	1,209	943	260	1,390	910	1,113
Madagascar	–	–	–	–	–	–	–
Mexico	–	–	–	–	–	–	–
Mozambique	–	–	–	–	–	–	–
Russia	–	–	–	–	–	–	–
Ukraine	–	–	40	20	1,420	1,997	1,583
United Kingdom	24	56	77	59	80	164	152
USA	–	–	–	–	–	–	–
Others	8	77	317	76	215	192	253

Source: Central Statistical Office (GUS)

graphite of Chinese origin has begun in 1997. In 2002 it alone exceeded 60% of the total supplies, while in 2009 – 80%, with a slight decrease in 2012. China and Germany has become the most important suppliers of amorphous grades; smaller ones have been Ukraine, France, the Czech Republic and Austria (formerly also Mexico and the USA). China and Germany have been also principal suppliers of flake graphite, with minor quantities coming from the United Kingdom and – previously – also from Brazil, Canada, Madagascar, and the USA (Tab. 52).

Table 53

Structure of natural graphite imports to Poland in 1991, 2002 and 2012 [%]

Tabela 53

Struktura importu grafitu naturalnego do Polski w latach 1991, 2002 i 2012 [%]

Country/Year	1991	2002	2012
Austria	60.8	5.9	0.0
Brazil	–	7.4	–
China	–	61.1	51.5
Czech Republic	3.2	10.4	1.1
France	11.6	–	1.9
Germany	12.7	13.3	16.3
Ukraine	–	0.1	23.2
United Kingdom	7.1	0.0	2.2
Others	4.6	1.8	3.7

Source: Central Statistical Office (GUS)

Over the last twenty years the average unit values of natural graphite importation to Poland generally oscillated between 2,000 and 4,000 PLN/t. The unit values of flake graphite deliveries from China increased in this period more than five times, to nearly 5,500 PLN/t last year. On the other hand, the unit costs of recent importation of amorphous graphite from Ukraine have dropped to ca. 200 PLN/t, while these for graphite supplied from other countries generally have ranged from 500 to 5,000 PLN/t (Tabs. 54, 55).

Precise data on the structure of natural graphite consumption in Poland are not available. Until the mid-1990s its amorphous variety had been primarily utilized for the production of refractories as well as brake friction linings, lubricants and seals. The commencement of the production of magnesia-carbon and alumina-carbon refractories for the iron and steel industry resulted in rapid growth in demand for flake graphite. The magnesia-carbon products contain from 10 to 15% of flake graphite with 90–95% C and flakes size between 150 and 750 μm (Galos 1999). They are applied in oxygen converter, electric arc furnaces

Table 54

Average unit values of natural graphite imports from selected countries [PLN/t]

Tabela 54

Średnie wartości jednostkowe importu grafitu naturalnego z wybranych kierunków [zł/t]

Country/Year	1992	1996	2000	2004	2005	2006	2007	2008	2009	2010	2011	2012
Total, average	**576**	**2,414**	**2,322**	**1,956**	**1,723**	**1,604**	**1,551**	**2,365**	**2,804**	**2,492**	**3,682**	**3,861**
Austria	542	1,528	1,243	1,760	1,547	2,501	2,529	1,815	6,077	–	3,848	3,345
China	–	1,048	1,899	1,882	1,375	1,696	1,359	2,196	2,475	3,163	4,667	5,487
Czech Republic	–	1,203	1,975	1,901	2,373	2,268	2,211	2,468	3,691	3,422	3,472	5,160
Germany	2,166	3,428	2,666	2,528	1,953	1,576	1,844	2,629	3,344	2,551	3,569	3,284
Ukraine	–	2,009	12,679	4,020	2,085	–	–	2,028	1,481	181	208	228
United Kingdom	1,955	3,583	8,318	1,176	1,742	3,421	1,418	1,387	3,371	2,126	3,014	3,521

Source: Central Statistical Office (GUS)

Table 55

Quantities and average unit values of natural graphite imports to Poland in 2012, by country

Tabela 55

Kierunki i średnie wartości jednostkowe importu grafitu naturalnego do Polski w 2012 r.

Country	Quantity [t]	Unit value [PLN/t]
Total imports	**6,817**	**3,861**
China	3,508	5,487
Czech Republic	77	4,558
France	130	1,181
Germany	1,113	3,284
Ukraine	1,583	228
United Kingdom	152	3,521

Source: Central Statistical Office (GUS)

and steelmaking ladles. The content of flake graphite in alumina-carbon products is higher (17–32%) with 90–99% C, and flakes size between 150 and 600 μm. The demand for both kinds of refractories has depended on the volume of the production of steel in continuos cast process (called COS). In recent years the consumption of flake graphite, mainly of Chinese and partly of German origin, in the domestic refractory industry can be estimated at above 6,000 tpy. The strong reduction of demand (by >50%) was recorded exclusively in 2009 due to temporary disturbances in the iron and steel industry. The major domestic producers of refractories utilizing graphite have been: ArcellorMittal Refractories of Cracow, Ropczyce Magnesite Plant, Vesuvius Skawina Refractories, and PCO Żarów. A potential new application of flake graphite is the production of refractory concretes for lining of blast furnace troughs, that will replace burned molded products (Suwak and Lipowska 2008; Pawełek et al. 2011). Its commencement in Poland could result in increase in demand and the need for flake graphite importation in future.

2.4. Magnesite and magnesia

Natural magnesite ($MgCO_3$) occurs in two forms: crystalline and compact (cryptocrystalline). Crystalline magnesite is more readily applied in the production of dead burned magnesite (roasted at 1,450–2,000°C) or fused magnesite (melted at temperature close to 3,000°C). The above-mentioned commodities are utilized almost exclusively in the refractory industry. Both varieties of raw magnesite, crystalline and cryptocrystalline, are suitable for manufacturing of calcined magnesite (calcination at 800–1,000°C), which is used mostly in the construction industry, glassmaking, and ceramics. Calcined magnesite is also a raw material for the production of other magnesium compounds applied in various fields, e.g. pharmacy, the pulp and paper industry, chemicals, plastics. Calcined, dead burned, and fused magnesite (magnesia), obtained from natural magnesite, can be substituted by appropriate grades of synthetic magnesia (MgO) of higher quality, which are obtained mainly from brines and seawater (Galos 1999).

The major magnesite raw materials traded internationally are: raw magnesite (with up to 47% MgO), calcined magnesite (magnesia) for industrial and agricultural purposes (88–98% MgO, calcined at 800–1,000°C and reactive with water), roasted (dead-burned) magnesite (magnesia) for the refractory industry (>88% MgO, usually 95–98% MgO, fired at 1,450–1,600°C, density 3.25–3.43 g/cm^3, not reactive with water), syntethic calcined and roasted magnesia (usually 97.0–99.5% MgO, 3.30–3.45 g/cm^3), as well as fused magnesia (97.0–99.9% MgO, density >3,45 g/cm^3) (Bilans gospodarki… 2014).

In Poland, compact magnesites with considerable admixture of silica (from 1% to as much as 14% SiO_2) occur in the Lower Silesia region. Their deposits are associated with serpentinite massifs of northern margin of Sowie Góry Unit (Sobótka and Gogołów–Jordanów massifs), and its southern margin (Szklary and Braszowice–Grochów massifs). At the moment there are six documented deposits with total resources of 14.5 Mt, including 4.3 Mt in the only one operated deposit of Braszowice (Mineral Resources Datafile... 2013). In addition, there are three prospective areas with total resources of 3.3 Mt in the vicinity of Braszowice and Szklary (Bilans perspektywicznych… 2011).

The extraction of magnesite in Lower Silesia, in the region of Ząbkowice Śląskie and Sobótka, has been carried out since the mid-nineteenth century. Until 1962 there was an underground mine near Ząbkowice Śląskie, and afterwards – the open-pit mine Konstanty was launched (to extract Braszowice deposit), the mining production of which ranged from 17,000 to 35,000 tpy. In the Sobótka region, until 1963 Sobótka deposit was mined, and then Wiry deposit started to be operated (max. 17,000 t in 1975). The total production of magnesite reached 55,000 t in 1975, while in the early 1990s it was reduced to 14,000 t. In the 1990s the mining output of Wiry underground mine was steadily declining until its closure in 1997. By 2003 the production of Konstanty mine in Braszowice ranged between 21,000 and 55,000 tpy, while in the following years it was expanding to as much as 84,000 t in 2012 (Tab. 56). That was, however, associated with a change of the way of the run-off-mine utilization.

Konstanty mine (Braszowice deposit) was operated Dolnośląskie Magnesite Works of Świdnica, which was transformed into Magnezyty Grochów. The latter one is currently the only magnesite manufacturer in Poland. The company, in course of grinding, optical sorting and classification, has processed low-quality magnesite-serpentinite run-off-mine into magnesite concentrates (crushed and ground) with 42–45% MgO. Since 2004 this production has significantly increased, approaching 65,000 t in 2007, with a reduction to 47,000 t in 2009 and growth to 84,000 t in 2012 (Tab. 56). The obtained several varieties of ground magnesite (called also R40 magnesite) have been an intermediate product utilized in numerous artificial fertilizers plants for manufacturing of multicomponent fertilizers NPKMg (recently 20,000–40,000 tpy), whereas crushed raw magnesite (25,000–40,000 tpy)

Table 56

Magnesite and magnesia statistics in Poland [‘000 t]

Tabela 56

Gospodarka magnezytami i magnezjami w Polsce [tys. t]

Item/Year	1990	1991	1992	1993	1994	1995	1996	1997
Raw magnesite								
Production	23.3	8.1	12.9	13.0	16.4	21.5	20.8	29.6
Imports	–	–	–	–	–	–	–	–
Exports	–	–	–	–	–	–	–	–
Apparent consumption	23.3	8.1	12.9	13.0	16.4	21.5	20.8	29.6
Magnesite and magnesia calcined, dead burned & fused								
Production	2.3	1.9	1.8	1.4	1.4	1.2	0.8	0.4
Imports	174.1	64.9	62.7	78.1	98.7	103.2	95.1	110.1
Exports	–	–	0.0	1.2	0.1	0.0	0.1	0.0
Apparent consumption	176.4	66.8	64.5	78.3	91.0	104.4	95.8	114.1

Table 56 cont.

Tabela 56 cd.

Item/Year	1998	1999	2000	2001	2002	2003	2004	2005
Raw magnesite								
Production	33.7	38.8	26.1	22.2	22.1	27.2	57.9	55.3
Imports	–	–	–	–	1.6	1.0	1.4	0.2
Exports	–	–	–	–	0.8	0.9	0.2	0.5
Apparent consumption	33.7	38.8	26.1	22.2	22.9	27.3	59.1	55.0
Magnesite and magnesia calcined, dead burned & fused								
Production	0.0	0.0	0.0	0.2	0.1	0.0	0.1	0.1
Imports	98.4	79.3	95.1	69.8	71.7	78.0	80.5	72.0
Exports	0.0	0.1	0.0	0.1	0.0	0.2	0.6	0.5
Apparent consumption	98.4	79.2	95.1	69.9	71.8	77.8	80.0	71.6

Item/Year	2006	2007	2008	2009	2010	2011	2012
Raw magnesite							
Production	62.5	65.0	60.0	47.0	63.0	75.0	84.0
Imports	0.2	0.2	6.0	4.8	3.2	1.9	1.5
Exports	–	–	1.4	0.5	0.1	0.1	0.1
Apparent consumption	62.7	65.2	64.6	51.3	66.1	76.8	85.4
Magnesite and magnesia calcined, dead burned & fused							
Production	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imports	103.5	110.5	120.9	81.4	116.4	140.0	116.3
Exports	0.6	2.8	2.4	0.2	0.9	0.5	3.3
Apparent consumption	102.9	107.7	118.5	81.1	115.5	139.5	113.0

Source: Central Statistical Office (GUS)

has been processed into magnesium compounds (e.g. magnesium sulfate) at domestic chemical plants. Braszowice plant has also utilized accompanying magnesite-serpentinite rock for the production of lower quality ground magnesite of R35 and R30 varieties. The total production of R40, R35 and R30 grades has recently ranged between 90,000 and 130,000 tpy. By 1989 the plant had produced low quality roasted magnesite (at most 14,800 t in 1975). Since 2001 Magnezyty Grochów has undertaken a small scale production (up to 50 tpy) of active (calcined) magnesium oxide with 70–85% MgO (Tab. 56).

Until 1997 magnesite from Wiry deposit was extracted by Strzeblowskie Kopalnie Surowców Mineralnych (SKSM) of Sobótka. The obtained magnesite concentrate was processed at the plant in Sobótka into calcined magnesite, earlier in an amount of 4,000–7,000 tpy, while in the 1990s – only 1,000–2,000 tpy. Due to competition of foreign suppliers, as well as deteriorating quality of the raw material and difficult geological and mining conditions in the mine, in 1997 the magnesite extraction was abandoned, and its calcination was stopped in 1998 (Tab. 56).

Table 57

Imports of magnesite and magnesia to Poland, by country [‘000 t]

Tabela 57

Kierunki importu magnezytu i magnezji do Polski [tys. t]

Country/Year	1990	1991	1992	1993	1994	1995	1996	1997
Total imports	**174.1**	**64.9**	**62.7**	**78.1**	**89.7**	**103.2**	**95.1**	**110.1**
– *raw magnesite*	–	–	–	–	–	–	–	–
– *calcined magnesite and magnesia**	*1.3*	*3.3*	*4.6*	*2.0*	*1.6*	*3.8*	*6.4*	*6.1*
– *dead burned magnesite**	*141.9*	*55.4*	*51.5*	*64.5*	*78.9*	*90.2*	*75.4*	*86.0*
– *dead burned magnesia**	*30.9*	*6.2*	*6.6*	*11.6*	*9.2*	*9.2*	*13.3*	*16.0*
– *fused magnesite and magnesia**	–	–	–	–	–	–	*0.0*	*2.0*
Australia	–	–	–	1.2	–	–	0.0	1.3
Austria	4.5	2.7	4.1	4.1	5.3	5.7	4.6	4.3
Brazil	39.6	20.4	32.2	26.0	30.1	36.3	30.2	32.4
China	–	–	11.1	29.7	38.4	30.1	21.5	20.9
France	–	0.0	0.1	0.1	0.2	2.5	4.3	4.3
Germany	–	–	–	1.4	0.6	0.3	0.3	0.5
Greece	–	0.0	–	–	–	–	–	–
Ireland	18.0	4.2	2.8	5.3	3.6	5.6	7.4	7.1
Israel	–	–	–	–	–	–	–	1.5
Korea, North	52.2	24.2	–	–	–	–	–	–
Netherlands	0.1	–	–	0.0	0.0	0.1	0.1	0.1
Russia	–	–	–	–	–	–	–	–
Slovakia	45.6	8.1	4.1	3.5	5.1	18.1	19.1	28.8
Spain	–	–	–	–	–	–	–	–
United Kingdom	12.8	2.0	3.8	5.3	5.6	3.5	5.8	6.3
Others	1.3	3.3	4.5	1.5	0.8	1.0	1.8	2.6

Table 57 cont.

Tabela 57 cd.

Country/Year	1998	1999	2000	2001	2002	2003	2004	2005
Total imports	**98.4**	**79.3**	**95.0**	**69.8**	**73.3**	**79.0**	**81.9**	**72.2**
– *raw magnesite*	–	–	–	–	*1.6*	*1.0*	*1.4*	*0.2*
– *calcined magnesite and magnesia* *	*7.1*	*5.4*	*5.6*	*5.6*	*7.4*	*5.5*	*7.4*	*5.6*
– *dead burned magnesite**	*76.3*	*59.6*	*71.9*	*49.4*	*49.5*	*61.1*	*63.9*	*58.9*
– *dead burned magnesia**	*9.2*	*9.0*	*12.6*	*8.5*	*8.8*	*5.4*	*4.2*	*2.5*^{s}
– *fused magnesite and magnesia**	*5.8*	*5.3*	*4.9*	*6.3*	*6.0*	*6.0*	*5.*^{s}	*5.0*
Australia	2.3	1.5	2.2	2.9	0.8	2.9	4.1	3.2
Austria	2.7	0.8	3.2	1.6	1.6	1.8	1.1	0.3
Brazil	24.7	19.3	28.7	18.4	21.5	22.6	28.1	24.5
China	24.0	19.4	17.7	13.8	11.6	18.0	13.6	13.2
France	5.2	4.3	4.2	3.4	3.2	3.6	3.2	3.4
Germany	0.8	0.3	0.2	0.5	0.1	0.1	0.3	1.6
Greece	–	–	–	–	–	–	0.5	0.6
Ireland	3.2	1.2	6.6	2.1	5.2	1.4	1.5	0.1
Israel	2.2	1.7	1.7	2.3	1.8	1.4	0.1	0.2
Korea, North	–	–	–	–	3.2	0.9	0.5	–
Netherlands	0.3	1.7	2.7	1.7	0.5	1.8	1.5	1.8
Russia	–	–	–	–	–	–	–	1.4
Slovakia	27.1	23.2	23.5	18.2	18.0	20.5	22.4	20.4
Spain	–	–	0.5	0.6	0.7	0.9	1.2	0.6
United Kingdom	3.9	4.2	1.1	2.4	2.8	1.2	1.1	0.2
Others	2.0	1.7	2.7	1.9	2.3	1.9	2.7	1.1

Until 2002 the trade of raw magnesite hadn't been reported. Currently, it has been marginal. The importation of raw magnesite exceeded 3,000 tpy only in the years 2008–2010 (Tabs. 56, 57). The main supplier has been Slovakia. Simultaneously, negligible re-exports of raw magnesite, mostly to the Czech Republic and Germany, have been registered.

Major magnesite raw materials imported to Poland have been dead burned, calcined and fused magnesite, as well as dead burned, calcined and fused magnesia derived from seawater or brines. Among them, the most important one in terms of volume has been dead burned magnesite. Its foreign deliveries, after significant reduction from ca. 140,000 t in 1990 to 50,000–65,000 tpy in 1991–1993, in the years 1994–2005 varied between 60,000 and

Table 57 cont.

Tabela 57 cd.

Country/Year	2006	2007	2008	2009	2010	2011	2012
Total imports	**103.7**	**112.1**	**126.9**	**86.2**	**119.6**	**141.9**	**117.8**
– *raw magnesite*	*0.2*	*1.6*	*6.0*	*4.8*	*3.2*	*1.9*	*1.5*
– *calcined magnesite and magnesia**	*5.9*	*6.3*	*5.1*	*6.6*	*10.5*	*7.2*	*7.0*
– *dead burned magnesite**	*89.3*	*94.7*	*107.8*	*68.5*	*95.2*	*107.7*	*97.2*
– *dead burned magnesia**	*3.3*	*3.5*	*2.0*	*1.3*	*4.7*	*19.1*	*6.1*
– *fused magnesite and magnesia**	*5.0*	*6.0*	*6.0*	*5.0*	*6.0*	*6.0*	*6.0*
Australia	1.2	0.9	4.8	5.6	8.7	17.9	16.7
Austria	0.2	0.2	0.2	0.2	0.4	0.8	1.2
Brazil	32.7	27.6	33.5	22.7	26.0	14.7	13.8
China	33.0	45.9	40.0	24.4	34.5	44.9	34.7
France	3.0	2.4	1.4	0.5	0.5	1.4	1.0
Germany	2.0	1.1	1.3	2.1	6.7	3.3	1.1
Greece	0.8	1.5	2.2	1.3	1.9	1.3	1.4
Ireland	–	1.2	1.1	0.4	1.4	2.2	1.7
Israel	0.6	0.3	0.2	0.1	0.4	0.3	0.3
Korea, North	–	–	–	–	–	–	–
Netherlands	1.8	1.7	0.5	0.7	1.7	16.4	3.9
Russia	1.7	0.7	1.1	0.9	2.5	2.9	1.9
Slovakia	25.5	22.2	36.5	24.5	30.8	33.5	36.4
Spain	0.0	–	0.0	0.1	0.2	0.1	0.6
United Kingdom	0.2	0.2	0.2	0.1	0.2	0.2	0.2
Others	1.0	2.2	3.9	2.6	3.4	2.0	2.9

* Until 1992 and since 2003 estimated quantities.
Source: Central Statistical Office (GUS)

90,000 tpy, with the exception of 2001–2002 when it dropped to around 50,000 tpy. In the period of 2006–2012 (except 2009), in turn, these imports stabilized at much higher levels of 90,000–108,000 tpy (Tab. 57). Large variations in the volume of deliveries of dead burned magnesite have been associated with volatile demand of its sole consumer, i.e. the refractory industry, that has been closely linked with a situation in the steelmaking, being the primary user of these commodities. The major dead burned magnesite foreign suppliers have been China, Brazil, and Slovakia (Tab. 58), minor – Australia, Russia, and several others.

Before 2000 imports of synthetic dead burned magnesia ranged between 9,000 and 16,000 tpy, while over subsequent years they were reduced to 2,000–6,000 tpy, partly as a consequence of competition from fused magnesite and magnesia. Only in 2011 it incidentally jumped to 19,000 t, due to increased importation from the Netherlands. Apart from the Netherlands, other foreign dead burned magnesia suppliers have been Ireland and Israel (Tab. 57). Since 1997 fused magnesite and magnesia have been imported to Poland from China, Australia and Israel. Their recent supplies have ranged from 5,000 to 6,000 tpy. Also related magnesium materials have been purchased, i.e. so-called co-clinkers Mg-Cr and Mg-Al, the deliveries of which from the United Kingdom and Austria haven't exceeded 1,000 tpy.

Table 58

The structure of magnesite and magnesia importation to Poland in 1992, 2002 and 2012 [%]

Tabela 58

Struktura importu magnezytów i magnezji do Polski w latach 1992, 2002 i 2012 [%]

Country/Year	1992	2002	2012
Australia	–	1.1	14.2
Austria	6.5	2.2	1.0
Brazil	51.4	29.3	11.7
China	17.7	15.8	29.5
France	0.2	4.4	0.8
Ireland	4.5	7.1	1.4
Netherlands	–	0.7	3.3
Slovakia	6.5	24.6	30.9
United Kingdom	6.1	3.8	0.2
Others	7.1	11.0	7.0

Source: Central Statistical Office (GUS)

Calcined magnesite and magnesia have been imported to Poland mainly from Spain, Greece, and other Western and Southern European countries, in total amounts of 5,000––7,000 tpy, with the exception of 2010 when their deliveries approached 10,000 t.

Since 2008 average unit values of magnesite and magnesia (calcined, dead burned, fused) importation to Poland have shown an upward trend, consistent with global tendencies. Most recently they have exceeded 1,800 PLN/t (Tabs. 59, 60). The unit values of various grades of magnesite and magnesia have been very diverse and amounted to: 1,200–6,000 PLN/t for calcined magnesite, 700–1,800 PLN/t for dead burned magnesite, 1,800–4,500 PLN/t for dead burned magnesia, 1,800–4,500 zł/t for fused magnesia, and even more than 6,000 PLN/t for special varieties of magnesia.

Table 59

Average unit values of magnesite and magnesia importation to Poland from selected countries [PLN/t]

Tabela 59

Średnie wartości jednostkowe importu magnezytu i magnezji do Polski z wybranych kierunków [zł/t]

Country/Year	1992	1996	2000	2004	2005	2006	2007	2008	2009	2010	2011	2012
Average unit value	373	820	1,057	1,107	1,049	1,022	1,045	1,160	1,496	1,485	1,877	1,804
– *raw magnesite*	*344*	*846*	*677*	*289*	*2,468*	*2,736*	*1,302*	*265*	*284*	*269*	*688*	*1,073*
– *calcined, dead burned, and fused magnesite and magnesia*	*807*	*806*	*1,124*	*1,121*	*1,045*	*1,019*	*1,041*	*1,206*	*1,570*	*1,527*	*1,893*	*1,813*
Australia	660	2,699	1,724	1,055	1,176	1,367	1,122	1,550	1,627	1,544	2,077	2,141
Brazil	341	634	893	871	842	873	856	1,019	1,439	1,233	1,395	1,404
China	175	594	1,188	1,394	1,389	1,083	1,134	1,499	1,941	1,970	2,468	561
Germany	458	2,546	4,857	2,654	1,825	1,689	1,837	1,523	1,968	1,942	1,731	2,618
Ireland	596	1,104	1,029	1,292	1,185	–	1,305	1,381	1,708	1,785	2,078	2,164
Netherlands	1,256	1,380	1,259	1,789	1,476	1,490	1,555	1,480	3,758	1,893	2,131	2,344
Slovakia	203	629	570	713	688	650	711	641	684	678	772	791

Source: Central Statistical Office (GUS)

Dead burned magnesite from Konstanty mine (Braszowice deposit), due to its low quality, until the end of the 1980s had been utilized as a minor component for manufacturing of common grade magnesite masses and mortars. In 1989 its roasting was discontinued, and the main applications of the raw magnesite have become the production of fertilizers (>50% of the total supplies), as well as sulfate and other magnesium compounds (up to 45%). Recently, magnesite raw materials for agriculture have been exclusively obtained from ground raw magnesite, whilst lower grades have been manufactured with addition of waste serpenitinite. Their total output has exceeded 80,000 tpy (Tab. 56).

Imported dead burned magnesite and magnesia, and since the late 1990s also fused magnesite and magnesia along with so-called co-clinkers Mg-Cr and Mg-Al, have been utilized mostly for the production of basic refractories, i.e. magnesite-based, magnesite--graphite, magnesite-chromite, magnesite-spinel et al., while the production of formed products (bricks etc.) of these types has been on explicit decrease (Tab. 61) in favour of unformed goods. Dead burned magnesite and magnesia of lower quality have been still commonly applied in manufacturing of traditional magnesia, magnesia-chromite, and

Table 60

Quantity and average unit values of magnesite and magnesia importation to Poland in 2012, by country

Tabela 60

Kierunki i średnie wartości jednostkowe importu magnezytu i magnezji do Polski w 2012 r.

Country	Quantity [‘000 t]	Unit value [PLN/t]
Total imports	**117.8**	**1,804**
– *raw magnesite*	*1.5*	*1,073*
– *calcined, dead burned and fused magnesite and magnesia*	*116.3*	*1,813*
Australia	16.7	2,141
Austria	1.2	2,190
Brazil	13.8	1,404
China	34.7	561
France	1.0	6,970
Germany	1.1	2,618
Greece	1.4	1,689
Ireland	1.7	2,164
Israel	0.3	24,310
Netherlands	3.9	2,344
Russia	1.9	1,025
Slovakia	364.0	791
Spain	0.6	1,926
United Kingdom	0.2	4,823

Source: Central Statistical Office (GUS)

magnesia-dolomite goods, as well as in unformed products of major importance, such as masses. On the other hand, the crucial application of high-grade dead burned magnesia, as well as of fused magnesite and magnesia, has been the manufacture of magnesia-graphite refractories. A key factor that has stimulated the development of these products utilization in the steelmaking was a finding that the purity of raw materials could directly influence the quality of final steel products. Therefore, in recent years high-grade magnesia-graphite products have been frequently utilized as a lining in the majority of oxygen converters as well as in slag zone walls of electric arc furnaces. Various grades of these commodities, applied in particular zones, differ from each other in terms of purity of magnesia and graphite, fused magnesia content, graphite content (usually 4–12% of high purity flake graphite), type and quantity of antioxidants, and the like (Galos 1999; Polski Przemysł Stalowy 2012).

Table 61

The production of formed basic refractories in Poland [‘000 t]

Tabela 61

Produkcja formowanych zasadowych materiałów ogniotrwałych w Polsce [tys. t]

Year	1990	1991	1992	1993	1994	1995	1996	1997
Production	180.2	122.5	117.2	115.1	125.8	127.0	120.3	124.5

Year	1998	1999	2000	2001	2002	2003	2004	2005
Production	109.8	89.5	100.4	82.8	74.1	71.4	73.9	63.3

Year	2006	2007	2008	2009	2010	2011	2012
Production	89.5	106.2	99.7	78.7	62.6	53.2	48.5

Source: Central Statistical Office (GUS)

Currently, the production of various grades of basic refractories containing dead burned and fused magnesite or magnesia has been carried out almost exclusively in two refractory plants: Ropczyce Magnesite Works and ArcelorMittal Refractories of Kraków. By 2001, the third important manufacturer of such products were Dolnośląskie Magnesite Works in Świdnica (no longer existing).

Calcined magnesite and magnesia of foreign origin – imported most recently in amounts from 5,000 to 10,000 tpy – have been mainly utilized in non-ceramic applications, i.e. the production of magnesium sulphate and other magnesium compounds, with minor importance of abrasives, Sorel cement etc. (Bilans gospodarki… 2014).

2.5. Bauxite and alumina for the refractory industry

It is estimated that on a global scale more than 95% of bauxite is processed into alumina (Al_2O_3), which in almost 90% is utilized in the production of primary aluminum (Bilans gospodarki… 2014). In consequence, non-metallurgical applications constitute only ca. 5% of bauxite and up to 10% of alumina consumption. One of the main non-metallurgical users of these raw materials is the refractory industry, where raw bauxite is utilized in the aluminous cement production, calcined (sintered) bauxite – in high-alumina refractories manufacturing, and calcined alumina – in both mentioned applications.

The most important types of refractory-grade bauxite are the following:

— raw bauxite for the production of aluminous cement in two varieties: high-iron and low-iron; high-iron bauxite contains commonly 45–59% Al_2O_3, 22–24% Fe_2O_3 and

up to 6% SiO_2, while low-iron bauxite – usually >70% Al_2O_3, 7–8% Fe_2O_3 and up to 2% SiO_2;
- calcined bauxite obtained from high quality raw bauxite with 59–61% Al_2O_3, max. 2% Fe_2O_3, max. 2.5% TiO_2, and 1.5–5.5% SiO_2, in course of calcination and sintering at ca. 1,650°C; mineral components of bauxite (gibbsite, diaspore and/or boehmite) are transformed primarily into corundum and mullite, while acompanying clayey minerals – into Al silicates and mullite; refractory calcined bauxite usually contains 86–90% Al_2O_3, max. 2.5% Fe_2O_3, max. 4% TiO_2, up to 7% SiO_2, and up to 0.6% of alkali; it is utilized for the production of high-alumina refractories (Galos 1999).

Calcined alumina is a synthetic raw material contaning over 99% Al_2O_3. It is obtained from alumina hydroxide $Al(OH)_3$ in course of processing of bauxite in the Bayer process. Alumina hydroxide can be processed (directly or indirectly) into the following varieties of aluminum oxide of refractory-grade:
- ordinary calcined alumina (of so-called smelter grade) obtained in course of calcination at 1,000–1,200°C,
- special calcined alumina – α-alumina (rich in α-corundum) obtained during calcination at over 1,400°C,
- reactive alumina being a product of very fine grinding of calcined alumina,
- tabular alumina (sintered alumina), produced by milling, pelletizing and sintering of α-alumina in shaft furnace at 1,700–1,850°C,
- fused alumina (electrocorundum) manufactured in course of melting of low-sodium calcined alumina in electric arc furnace (so-called white fused alumina, WFA) with addition of coke and iron filings* (Galos 1999).

All the domestic demand for raw and calcined bauxite, as well as for calcined alumina, has been covered by imports.

In the early 1970s, when Górka Refractory Raw Materials Plant (ZSO Górka) in Trzebinia manufactured aluminum hydroxide and commenced the production of aluminous cement, raw bauxite importation to Poland exceeded 50,000 tpy. The majority of this was utilized in the production of aluminum hydroxide. With gradual reduction of aluminum hydroxide production (ceased in 1984), raw bauxite deliveries were also declining. Until the mid-1990s up to 2,000 tpy of raw bauxite had been utilized for manufacturing of aluminous cement, while calcined alumina had been applied in the production of high grade Górkal-70 cement (Galos 1999). In the years 1996–2008, along with the development of aluminous cement production, the importation of refractory raw bauxite had been also recovered, up to over 42,000 tpy in the years 2006–2008. In the following three years they have dwindled by more than half, to ca. 20,000 t in 2011, and then revive to almost 35,000 t in 2012 (Tab. 62). Until 1996 the main supplier of raw bauxite of refractory grade to Poland

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* Moreover, in the same process from calcined bauxite the so-called brown fused alumina (BFA) can be obtained.

Table 62

Management of raw bauxite for the refractory industry in Poland ['000 t]

Tabela 62

Gospodarka boksytami surowymi dla przemysłu materiałów ogniotrwałych w Polsce [tys. t]

Item/Year	1992	1993	1994	1995	1996	1997	1998
Imports	0.8	0.8	0.3	1.6	2.8	4.3	2.0
Exports	–	–	–	–	–	–	–
Apparent consumption	0.8	0.8	0.3	1.6	2.8	4.3	2.0

Item/Year	1999	2000	2001	2002	2003	2004	2005
Imports	7.3	8.8	18.2	26.5	31.1	34.0	34.2
Exports	–	–	–	–	–	–	–
Apparent consumption	7.3	8.8	18.2	26.5	31.1	34.0	34.2

Item/Year	2006	2007	2008	2009	2010	2011	2012
Imports	42.4	43.2	43.2	36.7	25.9	20.3	34.5
Exports	–	–	1.0	–	7.0	–	–
Apparent consumption	42.4	43.2	42.3	36.7	18.9	20.3	34.5

Source: Central Statistical Office (GUS)

had been Hungary, with occasional imports from Croatia. In the years 1996–2000 some importation from Greece, Bosnia and Croatia appeared, while since 2001 Greece have become almost exclusive Polish supplier of this raw material (Tab. 63). In 2008 and 2010 incidental re-exports were also recorded, to Germany and the Czech Republic, respectively.

Calcined bauxite started to be imported by the domestic refractory industry in 1988, with the initial shipment of ca. 2,000 t from China (Galos 1999). Over the years 1989–1992 these deliveries increased to almost 7,400 t (Tab. 64), coming primarily from China, but mostly through German brokers/processors (Tab. 65). In the years 1993–2003, calcined bauxite was imported from Brazil, while since 2000 – from Guyana (also partly through brokers). After 2000, except for 2009–2010 and 2012, the importation of that raw material was regularly exceeding 20,000 tpy, the majority of which originated from China (Tabs. 65, 66). Some of these deliveries have been conducted through Western European brokers, primarily Dutch and German. In the last two years, Guyanese calcined bauxite, previously much more expensive than that of Chinese origin, became reasonably cheaper (e.g. in 2011: from Guyana – 662 PLN/t, from China – 1,438 PLN/t). In the years 2006–2011 calcined bauxite was re-exported in quantities ranging from 100 to 1,600 tpy (Tab. 64).

Table 63

Imports of raw bauxite for the domestic refractory industry, by country [‘000 t]

Tabela 63

Kierunki importu boksytów surowych dla krajowego przemysłu materiałów ogniotrwałych [tys. t]

Country/Year	1992	1993	1994	1995	1996	1997	1998
Total imports	**0.8**	**0.8**	**0.3**	**1.6**	**2.8**	**4.3**	**2.0**
Bosnia and Herzegovina	–	–	–	–	–	0.0	1.1
Croatia	–	–	–	1.6	–	2.7	0.7
Greece	–	–	–	–	0.2	1.6	0.2
Hungary	0.8	0.8	0.3	–	2.6	–	–

Country/Year	1999	2000	2001	2002	2003	2004	2005
Total imports	**7.3**	**8.8**	**18.2**	**26.5**	**31.1**	**34.0**	**34.2**
Bosnia and Herzegovina	3.2	0.2	–	–	–	0.1	–
Croatia	–	–	–	–	–	–	–
Greece	3.9	8.6	18.2	26.5	31.1	33.9	34.2
Hungary	–	–	–	–	–	–	–

Country/Year	2006	2007	2008	2009	2010	2011	2012
Total imports	**42.4**	**43.2**	**43.2**	**36.7**	**25.9**	**20.3**	**34.5**
Bosnia and Herzegovina	–	–	–	0.0	–	–	–
Croatia	–	–	–	–	–	–	–
Greece	42.4	43.2	43.2	36.7	25.9	20.3	34.5
Hungary	–	–	–	–	–	–	–

Source: Central Statistical Office (GUS)

Shipments of calcined alumina for the Polish refractory industry in the mid-1980s amounted to ca. 90,000–100,000 tpy. Around 90% of these supplies was utilized by ZSO Górka, primarily for the production of the so-called high-alumina grogs (substitutes of calcined bauxite and andalusite). The remaning 10% of imported calcined alumina (and minor amounts of fused alumina) were consumed by refractory plants in Gliwice, Skawina, and Żarów. In the years 1989–1992 domestic demand for refractories (also for high-alumina ones) was significantly reduced, resulting in collapse in the production of high-alumina grogs and significant decrease in the output of refractory aluminous cement. Moreover, the Polish refractory industry, in consistence with global tendencies, has started to utilize

Table 64

Management of calcined bauxite for the refractory industry in Poland [‘000 t]

Tabela 64

Gospodarka boksytami kalcynowanymi dla przemysłu materiałów ogniotrwałych w Polsce [tys. t]

Item/Year	1992	1993	1994	1995	1996	1997	1998
Imports	7.4	9.0	13.4	11.6	16.1	18.1	13.0
Exports	–	–	–	–	–	–	–
Apparent consumption	7.4	9.0	13.4	11.6	16.1	18.1	13.0

Item/Year	1999	2000	2001	2002	2003	2004	2005
Imports	6.8	14.5	17.6	21.8	23.6	22.9	22.8
Exports	–	–	–	–	–	–	–
Apparent consumption	6.8	14.5	17.6	21.8	23.6	22.9	22.8

Item/Year	2006	2007	2008	2009	2010	2011	2012
Imports	20.9	24.4	25.5	10.3	15.8	23.1	19.0
Exports	1.5	0.1	1.6	0.6	0.2	0.6	–
Apparent consumption	19.4	24.3	23.9	9.7	15.6	22.5	19.0

Source: Central Statistical Office (GUS)

Table 65

Importation of calcined bauxite for the domestic refractory industry, by country [‘000 t]

Tabela 65

Kierunki importu boksytów kalcynowanych dla krajowego przemysłu materiałów ogniotrwałych [tys. t]

Country/Year	1992	1993	1994	1995	1996	1997	1998
Total imports	**7.4**	**9.0**	**13.4**	**11.6**	**16.1**	**18.1**	**13.0**
Brazil	–	2.5	4.8	3.1	3.6	3.6	1.1
China	5.7	5.1	8.4	8.3	12.3	14.1	11.4
Germany	1.7	1.4	0.2	0.2	0.2	0.4	0.5
Guyana	–	–	–	–	–	–	–
Netherlands	–	–	–	–	–	–	–
United Kingdom	–	–	–	–	–	–	–
Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 65 cont.

Tabela 65 cd.

Country/Year	1999	2000	2001	2002	2003	2004	2005
Total imports	**6.8**	**14.5**	**17.6**	**21.8**	**23.6**	**22.9**	**22.8**
Brazil	1.6	2.0	0.6	1.1	0.0	–	–
China	4.7	11.8	14.8	19.1	22.9	21.5	19.0
Germany	0.5	0.5	0.2	0.1	0.1	0.4	2.3
Guyana	–	0.1	1.6	1.2	0.4	0.4	1.1
Netherlands	–	0.0	0.2	–	0.1	0.4	0.3
United Kingdom	–	–	–	–	–	–	–
Others	0.0	0.1	0.2	0.3	0.1	0.2	0.1

Country/Year	2006	2007	2008	2009	2010	2011	2012
Total imports	**20.9**	**24.4**	**25.5**	**10.3**	**15.8**	**23.1**	**19.0**
Brazil	–	–	–	–	–	–	–
China	14.4	19.4	19.1	4.8	10.0	8.8	9.5
Germany	1.3	1.5	3.5	2.1	1.3	1.3	1.4
Guyana	0.1	–	0.5	0.9	2.1	10.0	5.4
Netherlands	4.7	3.4	2.3	2.3	2.3	2.4	2.6
United Kingdom	0.4	–	–	–	–	0.5	0.0
Others	0.0	0.1	0.1	0.2	0.1	0.1	0.1

Source: Central Statistical Office (GUS)

imported calcined bauxite (since 1988) and andalusite raw materials (since 1992) that replaced high-alumina grogs from ZSO Górka. All these features contributed to strong decrease in both importation and consumption of refractory calcined alumina, down to ca. 9,000 t in 1991 (Galos 1999).

In the years 1992–2000 calcined alumina deliveries varied between 12,700 and 32,400 tpy (Tab. 67). Until 1997 their majority originated from Hungary, while in 1998 Germany appeared as a main supplier, with minor amounts brought from China (probably through Dutch brokers), the UK, Italy, Russia, Bosnia and others (Tab. 68). In the years 2000–2001 domestic demand for high-alumina refractories significantly diminished. Until 2000, the production of high-alumina grogs, sintered corundum and fused refractories in ZSO Górka was ceased, while the production of aluminous cement was transferred into Górka-Cement/Mapei. All these features resulted in reduced importation of refractory calcined alumina to Poland,

Table 66

Structure of imports of calcined bauxite for the domestic refractory industry
in the years 1992, 2002 and 2012 [%]

Tabela 66

Struktura importu boksytów kalcynowanych dla krajowego przemysłu materiałów ogniotrwałych
w latach 1992, 2002 i 2012 [%]

Country/Year	1992	2002	2012
Brazil	–	5.0	–
China	77.0	87.6	50.0
Guyana	–	5.5	28.4
Netherlands	–	–	13.7
Germany	23.0	0.5	7.4
Others	0.0	1.4	0.5

Source: Central Statistical Office (GUS)

Table 67

Management of calcined alumina for the refractory industry in Poland [‘000 t]

Tabela 67

Gospodarka aluminą kalcynowaną dla przemysłu materiałów ogniotrwałych w Polsce [tys. t]

Item/Year	1992	1993	1994	1995	1996	1997	1998
Imports	13.2	16.1	18.6	23.3	15.7	12.7	16.3
Exports	0.2	0.0	0.0	0.1	0.0	0.0	0.0
Apparent consumption	13.0	16.1	18.6	23.2	15.7	12.7	16.3

Item/Year	1999	2000	2001	2002	2003	2004	2005
Imports	16.4	32.4	6.5	9.0	23.1	21.9	16.6
Exports	0.0	–	0.0	0.0	0.0	0.4	0.1
Apparent consumption	16.4	32.4	6.5	9.0	23.1	21.5	16.5

Item/Year	2006	2007	2008	2009	2010	2011	2012
Imports	24.7	31.9	30.9	26.4	28.8	34.1	36.6
Exports	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Apparent consumption	24.7	31.9	30.9	26.4	28.8	34.1	36.6

Source: Central Statistical Office (GUS)

Table 68

Imports of calcined alumina for the domestic refractory industry, by country ['000 t]

Tabela 68

Kierunki importu aluminy kalcynowanej dla krajowego przemysłu materiałów ogniotrwałych [tys. t]

Country/Year	1992	1993	1994	1995	1996	1997	1998
Total imports	**13.2**	**16.1**	**18.6**	**23.3**	**15.7**	**12.7**	**16.3**
Bosnia and Herzegovina	–	–	–	–	–	–	–
China	–	–	–	–	–	–	–
France	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Germany	8.5	3.3	2.7	2.4	3.0	6.0	9.6
Hungary	3.5	12.1	15.6	20.3	12.3	6.4	6.0
Italy	–	–	–	–	–	–	–
Netherlands	1.1	0.5	0.1	0.3	0.0	0.0	0.1
Romania	–	–	–	–	–	–	–
Slovenia	–	–	–	–	–	–	–
Spain	–	–	–	–	–	–	–
Ukraine	–	–	–	–	–	–	–
Others	0.1	0.2	0.2	0.3	0.4	0.2	0.5

Country/Year	1999	2000	2001	2002	2003	2004	2005
Total imports	**16.4**	**32.4**	**6.5**	**9.0**	**23.1**	**21.9**	**16.6**
Bosnia and Herzegovina	–	–	–	–	–	–	0.0
China	0.0	–	0.0	0.0	0.1	0.1	0.6
France	0.1	0.3	0.3	0.5	0.3	0.4	0.6
Germany	11.7	31.9	6.0	8.2	14.7	8.1	15.1
Hungary	4.2	–	–	–	7.2	8.9	–
Italy	–	–	–	–	–	–	–
Netherlands	0.0	0.0	0.0	0.1	0.4	1.0	0.1
Romania	–	–	–	–	–	–	–
Slovenia	–	–	–	–	–	–	–
Spain	–	–	–	–	–	–	–
Ukraine	–	–	–	–	–	3.0	–
Others	0.4	0.2	0.2	0.2	0.4	0.4	0.2

Table 68 cont.

Tabela 68 cd.

Country/Year	2006	2007	2008	2009	2010	2011	2012
Total imports	**24.7**	**31.9**	**30.9**	**26.4**	**28.8**	**34.1**	**36.6**
Bosnia and Herzegovina	0.0	0.0	0.0	3.7	6.2	8.7	8.6
China	0.7	2.0	0.8	0.5	1.1	0.0	0.1
France	0.6	1.8	2.2	0.0	0.0	1.9	2.4
Netherlands	0.0	0.0	0.0	0.0	0.1	0.4	0.1
Germany	13.5	27.7	26.0	8.4	12.7	13.9	14.7
Hungary	–	–	–	6.0	6.7	7.0	6.2
Italy	6.1	0.1	0.2	0.2	0.2	0.3	0.3
Romania	–	–	–	–	–	–	3.0
Slovenia	–	0.0	1.5	0.5	1.7	1.5	0.9
Spain	–	–	–	7.0	0.0	0.0	0.0
Ukraine	3.5	–	–	–	0.0	–	–
Others	0.3	0.3	0.2	0.1	0.1	0.4	0.3

Source: Central Statistical Office (GUS)

Table 69

Structure of imports of calcined alumina for the domestic refractory industry in 1992, 2002 and 2012 [%]

Tabela 69

Struktura importu aluminy kalcynowanej dla krajowego przemysłu materiałów ogniotrwałych w latach 1992, 2002 i 2012 [%]

Country/Year	1992	2002	2012
Bosnia and Herzegovina	–	–	23.5
France	0.0	5.6	6.6
Germany	64.4	91.1	40.2
Hungary	26.5	–	16.9
Netherlands	8.3	1.1	0.3
Romania	–	–	8.2
Slovenia	–	–	2.5
Others	0.8	2.2	1.9

Source: Central Statistical Office (GUS)

to less than 10,000 tpy in 2001 and 2002. Since 2003, however, the deliveries have revived, predominantly up to above 20,000 tpy, with maximum of 36,600 t in 2012 (Tabs. 67, 68). In the years 2000–2008, the majority of alumina was imported from Germany (usually over 85%), with occasional larger deliveries from Hungary and Ukraine (in 2003–2004), as well as from Italy and Ukraine (in 2006). Since 2009 the share of Germany in the total imports has decreased to 30–40%, in favour of cheaper alumina grades (ca. 60% of deliveries, probably utilized in the production of aluminous cement) from Spain, Hungary, Bosnia and Romania, while higher quality raw materials from France, Italy, Slovenia, the UK and others have constituted the minority (Tabs. 68, 69).

From the mid-1990s to 2012 the average unit values of imports of raw refractory bauxite for the production of aluminous cement to Poland were quite stable, varying between 264 and 387 PLN/t (Tab. 70). The highest level of 387 PLN/t they reached in 2005. Since 2008 their fluctuations resulted mostly from PLN exchange rates.

The average unit costs of calcined refractory bauxite importation varied more widely: from 196 PLN/t in 1992 to max. 1,818 PLN/t (598 USD/t) in 2009 (Tab. 70). In the years 2010–2011 they decreased to 1,182 PLN/t (409 USD/t), mostly due to deliveries of cheaper Guyanese bauxite, with a revival in 2012 (Tabs. 70, 71). There were numerous reasons of such situation: fluctuations of exchange rates, volatility of international prices, as well as different costs of various contracts depending also on the quality of imported bauxite. It was clearly noticeable in 2008, when average unit values jumped over twice to 1,238 PLN/t (550 USD/t) from 753 PLN/t (268 USD/t) in 2007.

Also the average unit values of imported calcined alumina of refractory grade were very unstable, ranging from 426 to 2,694 PLN/t (Tab. 70). The reasons for such variability were similar as for calcined bauxite, but additionally they were influenced by the share of low- and high-quality alumina in the total importation (higher grades can be even a few times more

Table 70

Average unit values of bauxite and calcined alumina importation for the domestic refractory industry [PLN/t]

Tabela 70

Średnie wartości jednostkowe importu boksytów i aluminy dla krajowego przemysłu materiałów ogniotrwałych [zł/t]

Commodity/Year	1992	1996	2000	2004	2005	2006	2007	2008	2009	2010	2011	2012
Raw bauxite for aluminous cement production	80	290	285	345	387	367	305	264	34	325	321	338
Calcined bauxite of refractory grade	196	593	645	734	739	676	753	1,238	1,818	1,596	1,182	1,417
Calcined alumina of refractory grade	426	1,077	1,692	1,971	1,810	2,179	2,035	1,759	2,156	2,362	2,429	2,694

Source: Central Statistical Office (GUS), own calculation

expensive than lower grades). The significant increases in prices of imported calcined alumina were reported in 2000/2001: from 1,692 PLN/t (390 USD/t) to 2,334 PLN/t (568 USD/t), and in 2005/2006: from 1,810 PLN/t (560 USD/t) to 2,179 PLN/t (693 USD/t). In the following years the unit costs of importation were rising, up to 754 USD/t in 2008 (though expressed in Polish zlotys they dropped). In 2009, as a result of deliveries of cheaper grades of calcined alumina from Bosnia, Hungary and Spain, average unit values of imports decreased to 703 USD/t (while in PLN/t they grew). Since 2010 they have increased again, up to 2,694 PLN/t (825 USD/t) in 2012 (Tabs. 70, 72).

Table 71

Quantity and average unit values of calcined bauxite importation to Poland from selected countries in 2012, by country

Tabela 71

Kierunki i wartości jednostkowe importu boksytów kalcynowanych do Polski z ważniejszych kierunków w 2012 r.

Country	Quantity [t]	Unit value [PLN/t]
Total imports	**19,044**	**1,417**
China	9,523	1,555
Germany	1,352	1,633
Guyana	5,363	807
Netherlands	2,648	2,035

Source: Central Statistical Office (GUS), own calculation

Table 72

Quantity and average unit values of calcined alumina importation to Poland from selected countries in 2012

Tabela 72

Kierunki i wartości jednostkowe importu aluminy kalcynowanej do Polski z wybranych kierunków w 2012 r.

Country	Quantity [t]	Unit value [PLN/t]
Total imports	**36,577**	**2,694**
Bosnia and Herzegovina	8,596	1,620
France	2,379	5,846
Germany	14,669	3,384
Hungary	6,230	1,778
Romania	2,996	1,296
Slovenia	863	3,130

Source: Central Statistical Office (GUS), own calculation

In the 1980s the basic high alumina raw material consumed in the domestic refractory industry was calcined alumina of Hungarian origin. The largest amounts of this raw material – 80,000–90,000 tpy – were utilized in ZSO Górka plant in Trzebinia for the production of the so-called high alumina grogs, which were semi-products for manufacturing of high--alumina refractories in Skawina, Gliwice, Żarów and Częstochowa plants. Smaller amounts of calcined alumina were used in ZSO Górka for manufacture of the highest quality aluminous cement Górkal-70, sintered corundum Górkor, so-called mullite grogs, and fused corundum-zirconia refractories. Up to 5% of calcined alumina was consumed directly by the above mentioned refractory plants in the production of high-alumina refractories. Imported raw bauxite was of lower importance; it was applied in ZSO Górka in the production of aluminium hydroxide (until 1984) and lower grades of aluminous cement – Górkal-40 and Górkal-60. In the late 1980s and early 1990s, when domestic refractory industry switched to calcined bauxite and andalusite raw materials, the production of high alumina grogs in ZSO Górka started to decline, which was coupled with reduced consumption of calcined alumina. Since 1996, increasing amounts of raw bauxite were utilized in ZSO Górka in the production of aluminous cement, while calcined alumina still remained the main raw material for manufacturing of high quality aluminous cement, high alumina grogs and mullite grogs (though in decreasing amounts). As a result, in the late 1990s the manufacturers of high alumina refractories (both bricks and masses) utilized significant quantities of calcined bauxite and andalusite raw materials, small amounts of calcined alumina and decreasing amounts of high alumina grogs and mullite grogs from ZSO Górka, while the production of aluminous cement at that plant based on imported raw bauxite and calcined alumina (Galos 1999). Almost all of the high alumina products have been applied as refractories. The exceptions have been Górkor sintered corundum, partly utilized in the process of vacuum degassing of high quality steel, and Górkal-40 cement – in some special concretes (e.g. for hydrotechnical construction).

In 2000 a part of ZSO Górka was transferred into Górka-Cement company, which was subsequently sold to Italian company Mapei. As a result, the production of high alumina grogs and mullite grogs has been ceased in favour of aluminous cement. Until 2005, primarily lower grades of aluminous cement (mainly on the basis of imported raw bauxite) were manufactured there, while since 2005 the production of a new, modified high quality Górkal-70 cement from imported calcined alumina has been launched. That has been coupled with significant change in the consumption pattern of aluminous cement. The majority of varieties, mostly Górkal-40 and Górkal-50, have been utilized as a components of construction chemistry products, e.g. binders, dry mixes, self-levelling floorings, according to the main production profile of Mapei company. In practice, only the highest quality Górkal-70 cement has been currently utilized in the refractory industry for unshaped high alumina refractories (concretes, mortars, masses). High alumina bricks and other shaped products have been manufactured with the use of imported calcined bauxite and calcined alumina of appropriate quality. Detailed consumption pattern of these raw materials in Poland is difficult to ascertain. However, in Table 73 the approximate levels of their apparent consumption are given, though in some years, e.g. in 2001 and 2002 demand for alumina was probably underestimated, as it could have been supplemented from stocks. In general, until 2006 similar quantities of calcined bauxite and calcined alumina had been consumed: 20,000–25,000 tpy of each one (Tab. 73). Recent demand for calcined alumina can be assumed at more than 30,000 tpy (for both aluminous cement and high-alumina shaped refractories production), while calcined bauxite consumption in three plants: Vesuvius Poland of Skawina, ArcelorMittal Refractories of Kraków and PCO Żarów could have oscillated around ca. 20,000 tpy. Raw bauxite consumption in the production of aluminous cement at Górka-Cement plant has depended on the demand for lower quality aluminous cement, primarily from the construction chemistry branch, so it could have varied more widely, i.e. between 19,000 and 43,000 tpy.

Table 73

Estimated apparent consumption of bauxite and alumina in the domestic refractory industry in the years 2000–2012 ['000 t]

Tabela 73

Szacunkowe zużycie pozorne boksytów i aluminy w krajowym przemyśle materiałów ogniotrwałych w latach 2000–2012 [tys. t]

Commodity/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Raw bauxite for aluminous cement production*	8.8	18.2	26.5	31.0	34.0	34.2	42.4	43.2	42.3	36.7	19.0	20.3	34.5
Calcined bauxite of refractory-grade	14.5	17.6	21.8	23.6	22.9	22.8	19.4	24.2	23.9	9.7	15.6	22.5	19.0
Calcined alumina of refractory-grade	32.4	6.5	9.0	23.1	21.9	16.6	24.7	31.9	30.9	26.4	28.8	34.1	36.6

* Raw bauxite consumption for the total production of aluminous cement in Górka-Cement plant, utilized in various applications (not only refractory).

Source: Central Statistical Office (GUS), own calculation

Summary

This monograph presents a review of selected mineral raw materials utilized in ceramics (*sensu stricto*, i.e. in fine and technical as well as refractory ceramics) and the glass industry in Poland from their demand and supply side. The latter one has been presented from the point of view of domestic and foreign sources of raw materials, the list of which includes: kaolin, ceramic clays, feldspar and feldspar quartz, silica raw materials, limestone and dolomite for the production of glass-grade flour, industrial dolomite, andalusite, zirconium, graphite, magnesite and magnesia, as well as bauxite and alumina for the refractory industry.

The presented work contains a summary of the mining output, production, foreign trade, and consumption statistics of the above-mentioned raw materials in Poland as well as discusses the most important phenomena influencing their markets, giving the reasons for increased importation over the years 1990–2012. Some of the raw materials in question have been sourced from abroad despite the fact that their domestic sources are quite abundant, e.g. kaolin, glass-grade sand, industrial dolomite and limestone, or are available, e.g. quartz and quartzite, feldspar and feldspar-quartz, zirconium raw materials. This has been explained by either insufficient supplies of the raw materials of appropriate quality (e.g. kaolin, feldspar) or unfavourable location of consumers in relation to their domestic sources (e.g. glass-grade sand, kaolin, feldspar). Other raw materials such as andalusite and related, zirconium, graphite, have had to be imported due to their scarcity in Poland or – as in the case of magnesite for the refractory industry – low quality of raw magnesite from the sole domestic mine. For the raw materials of exclusively foreign origin the detailed imports in the years 1990–2012 by country, average values (in 1992 – the earliest data available, 1996, 2000 and 2004–2012), as well as percentage structure of deliveries in some years (for the majority in 1992, 2002, and 2012), have been given to depict the changing markets of these raw materials in Poland over the analyzed period.

A crucial factor that has influenced the mineral market in Poland from the demand side has been the soaring ceramic tiles and glass production. This has been followed by fast increase in the consumption of raw materials of both domestic and foreign origin (supplementing domestic supplies), especially kaolin, ceramic clays, feldspar and feldspar-quartz, silica sand, quartz, limestone and dolomite for glass applications, and zirconium. Opposite trends has been observed in the refractory industry, which has suffered a deep crisis of demand for refractories associated with the collapse in the iron and steel industry.

An analysis of past tendencies of demand for raw materials utilized in fine and technical ceramics in Poland has indicated that the greatest potential for growth of consumption is correlated with the ceramic tiles sector. This branch, with the production capabilities of 120–140 Mm^2/y of products characterized by the highest quality parameters and modern design, has been able to compete with foreign suppliers on the domestic market and expand sales abroad, especially in Eastern Europe. Indispensable for efficient utilization of domestic production potential in the forthcoming years will be the situation on the investment and construction markets, although much more important role than in previous years will play foreign sales. The future needs for kaolin and feldspar raw materials, as well partly for quartz flours, should be satisfied from domestic sources, while ceramic clays and zirconium will have to be imported.

The demand for glass-grade sand can be fully satisfied by domestic suppliers, both in terms of quality and quantity. An essential feature stimulating the production of flat glass in Poland has been the growth in the construction investments, both residential and commercial, thermal insulation works in the existing housing stocks, as well as development of the automotive industry.

Future demand for industrial dolomite in the refractory industry will depend on dolomite refractory goods consumption in the steelmaking. In recent years these products have been more frequently replaced by higher quality and more durable products made from imported sintered magnesite. Therefore in subsequent years it is anticipated that the production and consumption of dead burned dolomite will be reduced. Another factor contributing to this scenario is the depletion of resources of dolomite suitable for the manufacturing of highest quality grades. An alternative could be the introduction of two-step sintering of available varieties of rock of lower quality with intermediate stage of briquetting.

Foreign deliveries of zircon concentrates and flours fluctuated in a wide range, which resulted from variations in the needs of domestic recipients and substantial volatility in prices of these commodities. Over the years their most important consumer was the refractory industry. Since the mid-1990s, as zircon flours have been utilized in increasing extent as opacifiers in ceramic glazes, especially of ceramic tiles and sanitaryware, the primary user of zirconium raw materials in Poland has become the ceramics and probably this likely will remain in the near future.

Andalusite and related raw materials, exclusively of foreign origin, have been utilized in the domestic refractory industry for the production of high-alumina products. A volatile prosperity of the domestic iron and steel industry – the major consumer of these raw materials – has resulted in unstable demand for high-alumina refractories, and thus in the consumption of andalusite and related raw materials in Poland. The volume of future consumption will be also probably a function of the prosperity of that branch.

Precise data on the structure of natural graphite consumption in Poland are not available. The commencement of the production of magnesia-carbon and alumina-carbon refractories for the iron and steel industry resulted in growth of demand for flake graphite. The consumption of these graphite-based refractories fluctuated depending on the volume of steel production by continuous cast method. A potential new application of flake graphite, i.e. the production of refractory concretes for linings of blast furnace troughs, could result in increase of demand and importation of that graphite variety to Poland.

Other important raw materials in the refractory industry are magnesite and magnesia. Since raw magnesite mined in Poland has been utilized in the production of multicomponent fertilizers and crushed aggregates, the refractory-grade magnesite has had to be sourced exclusively from abroad. Large variations in the volume of these deliveries have been associated with a situation in the steelmaking, being the primary user of these refractory goods. The same circumstances refer to bauxite and alumina of refractory grade, the demand for which has been indirectly dependent on the domestic iron and steel industry market situation. These raw materials have been always imported to Poland, and in recent years utilized basically for the production of aluminous cement. However, the consumption pattern of that commodity has been dominated by the construction chemistry, while the refractory industry has utilized only the highest quality cement variety for the manufacture of high alumina refractories.

From the point of view of possible development of the resource base of discussed ceramic and glass-grade raw materials in Poland with regard to meet domestic industries' needs in the long term, it can be concluded that:

— Kaolin resources sufficiency is evaluated at around 290 years. The potential resource base (19.9 Mt) located in the Lower Silesia (Świdnica region) is recognised sufficiently to be mined in the future. The vast potential of kaolin supply development is also associated with the use of waste material generated in course of quartz sand washing.
— Resource base of ceramic clays in Poland is very diverse. White-firing clays are recognized in six deposits near Bolesławiec in the Lower Silesia (59.1 Mt), but their future development is – in general – unlikely due to unfavourable technical and economical conditions. White-firing clays frequently accompany stoneware and refractory clays in operated deposits of lignite, but their resources have not been documented. They have been also sourced from sandy-clayey sediments documented as foundry sand. Refractory clays reserves base is currently almost entirely limited to Jaroszów region in the Lower Silesia (recognized resources 42.2 Mt, perspective resources ca. 57 Mt), but their development can be difficult due to environmental and spatial reasons. The resources of stoneware clays in Poland are abundant (77.1 Mt), with good prospects for development.
— Domestic resource base of feldspar is rather poor. Prospects for the discovery of new deposits of feldspathic raw materials are limited to the regions that have been already explored, basically in the Izerskie foothills, and to deposits already documented in this area. However, due to environmental reasons (landscape parks, Natura 2000) the possibilities for enlargement of the existing resource base are small. An opportunity for development of domestic potassium feldspar supply can be associated only with Niemcza region (Kawia Góra – prognostic resources of 3.3 Mt). This, however, will require further detailed geological reconnaissance.

- Poland has relatively abundant resources of silica sand satisfying almost all the needs of the domestic glass industry. The sufficiency of its resources in deposits currently operated exceeds 90 years. The greatest potential in the country, both in terms of documented resources as well as prospects for new deposits discovery, is associated with the Tomaszów Syncline. The prognostic and prospective resources there can be estimated at over 270 Mt.
- Despite large limestone resources, domestic sources of raw materials for manufacturing of limestone flours of glass grade are limited because the majority of available limestone rocks are of insufficient purity. There are also no prospects for the discovery of raw materials of appropriate quality.
- The majority of domestic resources of dolomite and dolomitic marble cannot be a source for manufacturing of glass-grade flours of high purity, in particular due to very high content of Fe_2O_3. Considering the possibilities for development of resources of dolomitic marble appropriated for glass applications, in the Lower Silesia (Kłodzko region) several prognostic and prospective areas were outlined with total resources approaching 160 Mt. However, they are partly located within woodlands and Natura 2000 areas, which could be a barrier to future exploitation.
- Total resources of vein quartz for ceramic applications in deposits recognized in the Lower Silesia have been 6.6 Mt. There are some prospects for new deposits discovery in the Lower Silesia with total prognostic and perspective resources of around 4.2 Mt. Another important source of quartz flour will remain high purity silica sand deposits. Moreover, the reopening of some Lower Silesian vein quartz mines can be also expected (e.g. Stanisław). The only operated deposit of quartzite – Bukowa Góra in the Świętokrzyskie region – has been reclassified into the group of crushed and dimension stones. The possibilities for development of new deposits in this region are limited due to the protection of nature and environment. The resources of industrial quartzite of refractory grade left in 14 deposits in the Lower Silesia amounted to 2.4 Mt, however resumption of the mining activity there is doubtful mainly due to small resources (extraction unprofitable) or poor quality of the raw material as well as of low demand. Another siliceous raw material, quartz-schist from Jegłowa deposit in the Lower Silesia, due to its low quality ceased to be used in the refractory industry. There is very slight chance to restart the production of these grades.
- Raw dolomites for the production of refractory dead-burned dolomite in Poland are Triassic and – to a limited extent – Devonian dolomites of the Silesia-Kraków region. Since a couple of years the only source of raw dolomites for the production of refractory dead-burned dolomite in Poland has been Brudzowice deposit (resources 33.3 Mt), though suitable Triassic varieties are almost exhausted there, while the utilization of Devonian varieties will require a change of the sintering technology. The resources of undeveloped deposits of Devonian dolomite nearby Brudzowice, which could be potentially useful, amount to ca. 110 Mt. Moreover, some Devonian dolomites in the Świętokrzyskie region can be considered as a future source for dead-burned dolomite manufacturing.

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Market analysis of selected raw materials for the ceramic and glass industries in Poland over the years 1990–2012

Abstract

This monograph presents – in two parts – the analysis of selected ceramic and glass-grade raw materials management in Poland in the years 1990–2012. The first part discusses the raw materials of supralocal importance, both of domestic and foreign origin, while the second one has been dedicated to scarce raw materials, which due to the absence or insufficient quality of their domestic sources, have to be imported from abroad. Each chapter of the first part presents statistics of the mining output, production, foreign trade and consumption of particular commodity, its main manufacturers, the structure of supply with reference to domestic and foreign suppliers and quality of the raw materials offered, as well as the most important phenomena of local and global significance, which influenced the most the volume and structure of demand during the period in question. The second part has been focused on the raw materials imported mainly for the needs of the refractory industry, for which detailed directions and unit values of deliveries have been given as well as the markets of products derived therefrom have been characterized.

The first part of the monograph opens with a chapter concerning kaolin management in Poland. Both mineral resources for its production and the level of domestic supplies (including by-products of quartz sand washing) are sufficient (290 years) from the point of view of current and future needs of the largest users, i.e. the ceramic tiles and sanitaryware industries, the output of which has been closely correlated with kaolin consumption. The subject of importation will remain the grades of appropriate quality for fine ceramics, sanitaryware and papermaking, and – due to logistical reasons – also for certain plants of tiles and other ceramic goods. Assuming overcoming the crisis in the domestic construction industry, the prospects for further development of kaolin sector in the following years should be assessed optimistic. The potential for the production increase has both the leading domestic supplier – KSM Surmin-Kaolin (up to 100,000 tpy), and Polish producers of quartz sand.

The second chapter contains the presentation of domestic ceramic clays, i.e. white--firing, stoneware, and refractory ones. While stoneware clays occur in Poland quite abundantly, other varieties – especially white-firing clays and refractory clays of high purity – have to be imported. Similarly as in the case of such mineral raw materials

as kaolin and feldspar, the largest consumer of ceramic clays has been the ceramic tile industry, utilizing these clays for the manufacture of stoneware, gres (porcelain) and – although in much smaller and decreasing scale – also for faience tiles. Important users of these raw materials have been also shaped stoneware goods (other than tiles), chamotte refractories, sanitaryware, and semi-vitreous china-ware. In subsequent years it is expected that the demand for ceramic clays in the ceramic tile and sanitaryware industries will maintain at recent levels or will slightly improve (assuming the construction sector recovery), while their consumption in the refractory industry will fluctuate depending on economic cycle showing generally a downward trend, and in other applications – will remain marginal.

The third chapter has been dedicated to feldspar and feldspar-quartz raw materials. Together with kaolin and ceramic clays they constitute the basic mineral raw materials for fine and technical ceramics. In recent several years their consumption has increased remarkably, mainly as a result of rocketing growth of the production of ceramic tiles. Despite limited prospects for resource base expanding, future supplies of raw materials for the needs of their largest user from domestic sources should be assessed as sufficient mainly due to the recovery of spinoff alkali-rich fines generated in course of granite crushed aggregates manufacturing. Expected revival in the construction industry, which has been a major recipient of ceramic goods, will probably result in the necessity of supplementary supplies of feldspathic raw materials from abroad. Traditionally, also higher grades of feldspar for fine ceramics will continue to be imported.

Glass-grade sands, presented in the fourth chapter, constitute a group of mineral raw materials, the demand for which can be fully met from domestic sources, both in terms of quantity and quality. The relatively abundant resources of silica sand allow satisfying almost all the needs of the domestic glass industry for at least 90 years. Prospects for extending the current resource base refer only to the Tomaszów Syncline, where more than 80% of the resources have been already documented. This unevenness of deposits distribution in the country has been a problem to cover the raw material needs of glass producers, which are scattered throughout the country. For this reason, in recent years the irregular and small imports both of cheaper raw material from Ukraine and quartz sand of the highest grades from Germany have been recorded. The increased production of glass, especially the container and flat ones, and the realization of new investments, as well as planned modernization of several glassworks, may result in further gradual increase in demand for glass-grade sand, while existing sources of supply will remain the same, i.e. mainly domestic deposits.

The development of glass production has also resulted in increased demand for other glass-grade raw materials, although consumed in much smaller quantities, i.e. limestone and dolomite flours, which have been characterized in the following two chapters of the monograph. The demand for them has been satisfied predominantly from domestic sources and supplemented by small importation. Despite the large resource base of limestone, dolomite and dolomitic marble, domestic sources of raw materials for the production of flours of appropriate quality are limited, due to their insufficient purity, especially too high content of colouring oxides.

The seventh chapter presents the market of quartz raw materials, predominantly utilized in the ceramic industry, in particular in manufacturing of porcelain, frits and glazes (quartz), as well as – on a small scale – in the production of siliceous refractory materials (quartzite, quartz-schist). For many years vein quartz from the Lower Silesian deposits was utilized as a raw material for fine ceramics. The deficit of high quality quartz flour on the Polish market was complimented by importation. In recent years, the consumption of flour obtained by grinding of high purity quartz sand from domestic deposits (Osiecznica, Grudzeń Las) has been developed. In the coming years, the increase in demand for these flours is very probable. Furthermore, the resumption of the extraction of some vein quartz domestic deposits is also considered. Main consumer of these raw materials, i.e. affected by a deep crisis the tableware porcelain industry, has significantly reduced the demand. Other users, including the manufacturers of electrotechnical porcelain, frits and glazes, have utilized much smaller quantities of quartz flours. Demand for quartzite in the last twenty years has been significantly reduced due to technological developments in the metallurgy. The only domestic manufacturer of industrial quartzite has been Bukowa Góra mine in Łączna. In the following years neither the increase in demand for this raw material in the refractory industry is foreseen nor a change of its foreign suppliers (mainly Ukraine). Quartz-schist for decades was utilized as natural refractory material, initially in a form of shaped lining elements in furnaces construction, and then as a powder for siliceous mortars and mixes. This raw material has been exclusively extracted at Jegłowa mine in the Lower Silesia. Due to the deterioration of the run-off-mine quality and decrease in demand for products of this type, their production has been discontinued and its resumption is not planned.

The first part of the monograph ends with a chapter discussing the management of dolomites utilized in the production of refractories. Despite numerous dolomite deposits in Poland, the only ones suitable for dead burned dolomite manufacturing have been these of the Silesia-Cracow region. Future demand for these raw materials will be conditioned by the scale of utilization of dead burned dolomite in steel mills, where they have increasingly been replaced by products based on imported dead burned magnesia. Furthermore, due to the depletion of resources of Triassic dolomites of appropriate quality, the utilization of other varieties of the raw material (e.g. Devonian) will require the implementation of two-step sintering process with intermediate stage of briquetting.

The first chapter of the second part of the monograph applies to zirconium raw materials. In spite of the potential possibilities of their recovery from domestic sources, their overall supply in Poland has come from abroad. For many years their principal consumer was the refractory industry. However, due to the development of ceramic tiles and sanitaryware production since the mid-1990s, increasing amounts of zircon flour have been utilized in the manufacture of ceramic glazes. That application has recently dominated the structure of zirconium raw materials consumption in Poland and presumably, despite considerable reduction of their deliveries due to high prices, in the near term is likely to maintain this position.

The remaining chapters present basic scarce raw materials of the refractory industry, i.e. andalusite and related materials, graphite, magnesite and magnesia, as well as bauxite and alumina. A factor determining the level of their consumption has been – and will probably remain in the future – a volatile prosperity of the domestic steel industry, which has been the major consumer of refractories (65–70% of demand). While the supplies of andalusite raw materials, graphite, and bauxite and alumina have always come from abroad, in the case of magnesite and magnesia the importation has become their only source since the change of the application of raw magnesite concentrate from the only magnesite deposit mined in Poland – Braszowice, which started to be exclusively utilized in manufacturing of multicomponent fertilizers.

Analiza rynku wybranych surowców przemysłu ceramicznego i szklarskiego w Polsce w latach 1990–2012

Streszczenie

Niniejsza monografia przedstawia w dwóch częściach analizę gospodarki wybranymi surowcami ceramicznymi i szklarskimi w Polsce w latach 1990–2012. W części pierwszej omówiono surowce o znaczeniu ponadlokalnym, pochodzące zarówno z rodzimych źródeł, jak i importowane, druga zaś została poświęcona surowcom deficytowym, które ze względu na brak ich źródeł w Polsce bądź niedostateczną jakość występujących w kraju kopalin muszą być sprowadzane z zagranicy. W każdym z rozdziałów części pierwszej przedstawiono statystyki wydobycia, produkcji, handlu zagranicznego i zużycia poszczególnych surowców, omówienie ich producentów, struktury podaży na rynku krajowym z uwzględnieniem dostawców krajowych i zagranicznych oraz jakości pozyskiwanych surowców, a także najważniejsze zjawiska o znaczeniu lokalnym i globalnym, które decydowały o kształtowaniu się poziomu i struktury zapotrzebowania w omawianym okresie. W części drugiej skoncentrowano się na surowcach sprowadzanych w głównej mierze dla potrzeb przemysłu materiałów ogniotrwałych, dla których przedstawiono szczegółowo kierunki i wartości jednostkowe importu, a także charakterystykę rynku wytwarzanych z nich wyrobów.

Część pierwszą monografii otwiera rozdział dotyczący gospodarki kaolinem w Polsce. Zarówno zasoby kopalin do jego produkcji, jak i poziom krajowej podaży (w tym ubocznej, z procesu płukania piasków kwarcowych), są wystarczające (290 lat) w stosunku do obecnych i przyszłych potrzeb największych konsumentów, tj. przemysłu płytek ceramicznych i wyrobów sanitarnych, których produkcja jest ściśle skorelowana z poziomem zużycia kaolinu. Przedmiotem importu pozostaną gatunki o odpowiedniej jakości dla przemysłu porcelanowego, wyrobów sanitarnych i papierniczego, a także niektórych zakładów płytek i innych wyrobów ceramicznych, co wynika ze względów logistycznych. Zakładając przełamanie kryzysu w krajowym budownictwie, perspektywy dalszego rozwoju branży kaolinowej w najbliższych latach należy oceniać optymistycznie. Możliwościami rozwoju podaży dysponuje bowiem zarówno wiodący krajowy dostawca – KSM Surmin-Kaolin (do 100 tys. t/r), jak i rodzimi producenci piasków kwarcowych.

Rozdział drugi zawiera omówienie krajowej gospodarki iłami ceramicznymi, w tym biało i barwnie wypalającymi się (kamionkowymi) oraz ogniotrwałymi. O ile iły kamionkowe

występują na terenie Polski stosunkowo obficie, to pozostałe odmiany – zwłaszcza iły biało wypalające się i wyższej czystości iły ogniotrwałe – muszą być importowane. Podobnie jak w przypadku innych surowców (kaolin, surowce skaleniowe), największym konsumentem iłów ceramicznych jest przemysł płytek ceramicznych, wykorzystujący je do produkcji płytek kamionkowych i gresowych, a także – choć na coraz mniejszą skalę – również fajansowych. Ważnymi użytkownikami tych iłów są także przemysły: formowanych wyrobów kamionkowych (innych niż płytki), wyrobów szamotowych, sanitarnych oraz porcelitowych. Ocenia się, że w najbliższych latach zużycie iłów ceramicznych w przemyśle płytek ceramicznych i wyrobów sanitarnych utrzyma się na dotychczasowym poziomie lub nieco wzrośnie (spodziewane ożywienie w budownictwie), w przemyśle wyrobów ogniotrwałych – będzie zasadniczo wykazywało tendencję spadkową, zaś u pozostałych użytkowników – pozostanie marginalne.

Rozdział trzeci został poświęcony surowcom skaleniowym i skaleniowo-kwarcowym. Podobnie jak kaolin i iły ceramiczne, są one podstawowymi surowcami ceramiki szlachetnej i technicznej. Ich zużycie w ostatnich kilkunastu latach wybitnie się zwiększyło, głównie za sprawą rozwoju produkcji płytek ceramicznych. Mimo stosunkowo niewielkich możliwości powiększenia szczupłej krajowej bazy zasobowej, perspektywy zaspokojenia potrzeb największego konsumenta tych surowców z krajowych źródeł rysują się optymistycznie, głównie w związku z ich ubocznym pozyskiwaniem w toku produkcji granitowych kruszyw łamanych. Spodziewane ożywienie gospodarcze, a zwłaszcza przełamanie kryzysu w budownictwie, będącym ważnym odbiorcą wyrobów ceramicznych, będzie skutkowało koniecznością uzupełniania rodzimej podaży surowców skaleniowych importem. Tradycyjnie sprowadzane będą również wyższe ich gatunki dla przemysłu ceramiki szlachetnej.

Przedstawione w rozdziale czwartym piaski szklarskie stanowią grupę surowców, na które zapotrzebowanie może być w całości zaspokajane przez krajowych dostawców, zarówno pod względem ilościowym, jak i jakościowym. Pozwala na to stosunkowo bogata baza zasobowa, której wystarczalność przy obecnym poziomie wydobycia ocenia się na co najmniej 90 lat. Perspektywy jej powiększenia ograniczają się do Niecki Tomaszowskiej, gdzie znajduje się ponad 80% zasobów obecnie udokumentowanych. Ta nierównomierność rozmieszczenia zasobów stanowi problem zaspokojenia potrzeb surowcowych branży szklarskiej, której producenci rozsiani są po całym kraju. Z tego powodu w minionych latach można było obserwować okresowy i nieznaczny import zarówno tańszego surowca z Ukrainy, jak i piasków najwyższych klas z Niemiec. Rosnąca produkcja szkła, zwłaszcza opakowaniowego i płaskiego, realizacja nowych inwestycji, a także plany modernizacji wdrażane w kilku hutach szkła, będą przypuszczalnie skutkować stabilnie rosnącym popytem na piaski szklarskie, przy zachowaniu dotychczasowych kierunków dostaw, praktycznie w całości ze złóż krajowych.

Rozwój produkcji szkła wymusił również wzrost zapotrzebowania na inne surowce przemysłu szklarskiego, zużywane w znacznie mniejszych ilościach, m.in. mączki wapienne i dolomitowe, które zostały scharakteryzowane w kolejnych dwóch rozdziałach monografii. Popyt na te surowce zaspakajany jest w większości ze źródeł krajowych i uzupełniany niewielkim importem. Pomimo dużej bazy zasobowej zarówno wapieni, jak i dolomitów oraz marmurów dolomitycznych, ze względu na ich niewystarczającą czystość (szczególnie zbyt wysoką zawartość tlenków barwiących) krajowe źródła kopalin do produkcji tych mączek są ograniczone.

Rozdział siódmy przedstawia rynek surowców kwarcowych stosowanych w przemyśle ceramicznym, zwłaszcza porcelanowym oraz do wytwarzania fryt i szkliwa (kwarc), a także – na niewielką skalę – w produkcji krzemionkowych materiałów ogniotrwałych (kwarcyt, łupki kwarcytowe). W ceramice szlachetnej przez wiele lat wykorzystywano surowiec pochodzący z dolnośląskich kopalń kwarcu żyłowego, uzupełniając deficyt wysokiej jakości mączek kwarcowych importem. W ostatnich latach rozwinęło się zużycie mączek kwarcowych otrzymywanych w wyniku mielenia wysokiej jakości piasku kwarcowego z krajowych złóż (Osiecznica, Grudzeń Las). W najbliższych latach prawdopodobny jest dalszy wzrost konsumpcji tych mączek oraz powrót do eksploatacji krajowych złóż kwarcu żyłowego. Główny konsument tych surowców – branża porcelany stołowej, dotknięta głębokim kryzysem, znacznie ograniczyła wielkość zużycia. Pozostali użytkownicy, tj. ceramika elektrotechniczna, wytwórcy fryt i szkliw, stosują zdecydowanie mniejsze ilości tych mączek. Zapotrzebowanie na kwarcyt w ciągu ostatnich dwudziestu lat znacznie się zmniejszyło w konsekwencji zmian technologicznych w hutnictwie. Jedynym krajowym producentem kwarcytów przemysłowych jest kopalnia Bukowa Góra w Łącznej. W najbliższych latach nie przewiduje się wzrostu zapotrzebowania na te surowce w przemyśle materiałów ogniotrwałych, jak też zmian kierunków ich dostaw (głównie Ukraina). Łupki kwarcytowe były przez dziesięciolecia materiałem ogniotrwałym stosowanym pierwotnie w postaci kształtek w budowie pieców, a następnie mieliw do krzemionkowych mas i zapraw. Jedynym miejscem ich pozyskiwania była kopalnia Jegłowa na Dolnym Śląsku. W związku z pogorszeniem jakości kopaliny oraz spadkiem zapotrzebowania na tego typu wyroby zaniechano ich produkcji i nie przwiduje się jej wznowienia.

Część pierwszą monografii zamyka rozdział omawiający gospodarkę dolomitami stosowanymi w produkcji materiałów ogniotrwałych. Mimo licznych złóż kopalin dolomitowych na terenie Polski, jedynie te z rejonu śląsko-krakowskiego były stosowane do produkcji dolomitów prażonych. Przyszłe zapotrzebowanie na te surowce będzie związane ze skalą wykorzystania dolomitowych materiałów ogniotrwałych w hutach stali, gdzie są one coraz częściej zastępowane wyrobami produkowanymi na bazie importowanego magnezytu prażonego. Ponadto, w związku z wyczerpywaniem się zasobów odpowiedniej jakości dolomitów triasowych, wykorzystanie innych odmian tej kopaliny (np. wieku dewońskiego) będzie wymagało wdrożenia dwuetapowego procesu spiekania z pośrednim stadium brykietowania.

Pierwszy rozdział drugiej części monografii dotyczy surowców cyrkonowych. Mimo istnienia potencjalnych możliwości ich pozyskiwania ze źródeł krajowych, całość ich podaży w Polsce pochodzi z zagranicy. Głównym użytkownikiem tych surowców przez wiele lat był przemysł wyrobów ogniotrwałych. Wraz z rozwojem produkcji płytek ceramicznych i wyrobów sanitarnych, od połowy lat dziewięćdziesiątych XX w. coraz większe ilości mączek cyrkonowych były stosowane do wytwarzania szkliw ceramicznych. Ten kierunek zdominował strukturę użytkowania surowców cyrkonowych w Polsce i przypuszczalnie, mimo znacznego ograniczenia ich dostaw w związku z wysokimi cenami w ostatnich latach, w najbliższym okresie utrzyma tę pozycję.

W kolejnych rozdziałach przedstawiono podstawowe deficytowe surowce przemysłu materiałów ogniotrwałych, tj. andaluzyt i surowce pokrewne, grafit, magnezyty i magnezje, a także boksyty i aluminę. Czynnikiem decydującym o poziomie ich zużycia jest i pozostanie zmienna kondycja krajowego hutnictwa żelaza, głównego użytkownika materiałów ogniotrwałych (65–70% zużycia). O ile podaż surowców andaluzytowych, grafitu oraz boksytów i aluminy zawsze pochodziła z zagranicy, to w przypadku magnezytów i magnezji import stał się ich jedynym źródłem stosunkowo niedawno. Było to spowodowane zmianą głównego kierunku wykorzystania koncentratów magnezytu surowego z jedynego eksploatowanego w Polsce złoża Braszowice, obecnie użytkowanych wyłącznie w produkcji nawozów wieloskładnikowych.