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A PROSPECTIVE STUDY OF INORGANIC WASTE FROM POLISH CHEMICAL INDUSTRY

ANALIZA PROBLEMU ODPADÓW NIEORGANICZNYCH Z POLSKIEGO PRZEMYSŁU CHEMICZNEGO

Abstract

The paper presents quantitative and qualitative analysis of inorganic waste generated by Polish chemical industry in the years 2004-2010. Analysis of the impact of waste issue on chemical branch development as well as on local society has been attempted. Waste group 06 (classification according to the Waste Catalogue) [1] generated by chemical enterprises (sections 19 - 22 of the Polish Classification of Activity) has been analyzed. We describe the technologies generating the significant amount of waste group 06 and present the methods of decreasing their waste streams. European environmental policy requirements, economy and market conditions as well as technological and research trends in the concerned area are also discussed. We further present the foundations of foresight methodology for inorganic waste, in particular its group 06. The paper reports recent results and methodology elaborated within the research project on "Inorganic wastes of chemical industry – technological foresight" [2] co-funded by the Operational Programme Innovative Economy, which is one of the six national programmes under the National Strategic Reference Framework, and supervised by the Polish Ministry of Science.

Keywords: foresight, inorganic waste, inorganic industry, waste management

Streszczenie

W artykule przedstawiono analizę ilości i rodzaju odpadów nieorganicznych wytworzonych przez polski przemysł chemiczny w latach 2004-2009 oraz podjęto próbę analizy wpływu problemu odpadów na rozwój tego przemysłu i na odbiór społeczny zakładów chemicznych. Analizowano odpady grupy 06 według katalogu odpadów [1] wytwarzane przez podmioty gospodarcze posiadające kody PKD z działów 19 do 22. Omówiono politykę ekologiczną UE, warunki ekonomiczno-rynkowe, dostępne technologie i trendy w badaniach. Przedstawiono także podstawy metodologii foresightu odpadów grupy 06. Publikacja powstała w oparciu o raporty stanu wiedzy i metodologiczne opracowane w ramach realizacji projektu „Odpady nieorganiczne przemysłu chemicznego – foresight technologiczny"[2].

Słowa kluczowe: prognozowanie, odpady nieorganiczne, przemysł nieorganiczny, gospodarka odpadami

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1. Introduction

For chemists, it is obvious that the processing of some substances into others by the chemical industry and the production of chemical output for other industries as well as consumers is a vital link in any economy. In addition, the cooperative ties with other market segments are widespread. However, it seems that society perceives chemistry and the chemical industry more as a threat to the environment and human health than an indispensible part of sustainable economic development. The inorganic industry mainly produces base chemicals, unknown to an average user, in addition to mineral fertilizers. It uses natural mineral resources, of which useful constituents are utilized, leaving behind useless waste, and it is based on outdated and energy-intensive technologies. The question arises whether Poland has the necessary economic, scientific and human resource potential to further develop this industry. The results of this foresight project should answer these questions, at least in part. While considering the issue of development in any industry, the need to maintain the principles of sustainable development (the balance between the needs of the economic, social and natural environment) should not be forgotten. It is not necessary to justify the economic need for forecasting the development of the economy and its various branches. After disappointing forecasts based solely on statistical methods, a flexible approach to research gained importance in the 1990s. A holistic vision of the future was created, a process called foresight. This process should be understood as a participative and systematic way of gathering information in order to build a medium- or long-term vision of development, its multi-dimensional directions and priorities based on the current state of science, technology, economy, social awareness and their interrelationships [3]. Increasingly popular industry foresight is used to create a vision of development for a sector under examination by determining the key factors that should play an important role in the development of the industry (Fig. 1).

The sustainable use of resources in the long term requires taking into account their availability, ensuring safety of supply and the protection of ecosystems. At the same time, it is important to maintain the capacity of the environment to absorb emissions and pollutants. Improving the sustainability of production requires improving efficiency, the adoption of innovative technological and management solutions as well as better monitoring and environmental control. The objectives of waste prevention according to the EU policy are: to reduce emissions, to reduce hazardous substances in material streams and their dissipation, and to improve natural resource usage efficiency [4]. In the European Commission and Parliament, it is generally acknowledged that the chemical industry is a potential threat to the environment and the tasks that have been set may prove incompatible with economic realities. Fulfilment of obligations under the REACH Regulation, the implementation of the Revised Emissions Trading Scheme Directive in 2013 and the Industrial Emissions Directive for 2016 could preclude the operation of an energy-intensive chemical industry in Europe and Poland. At the same time, the demand for chemical products increases with society's wealth [5]. This poses a threat to the operation of manufacturing basic inorganic chemicals, including fertilizers, in Poland. The industry, next to crude oil processing, is the largest chemical industry sector in Poland in terms of tonnage and value.

The chemical industry in Poland has made significant progress in reducing its environmental impact 'at source', and even progress in the environmental awareness of companies and workers has recently been apparent. However, not all changes are possible. The lack of resources, research and development of innovative technologies stand in the way of further-reaching changes and development [5, 6].

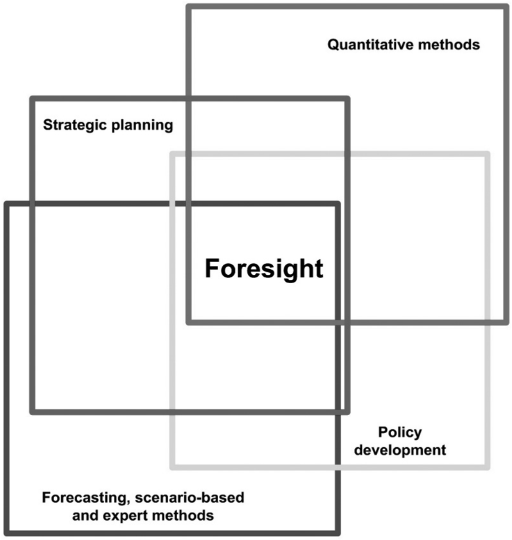

Fig. 1. The research areas affecting foresight (PBF)

Rys. 1. Obszary badawcze wpływające na *foresight*

An approach to the problem of waste should evolve along with technological changes and changes in the environment. Although there is practically no technology that does not generate chemical products of little or no use, a modern ecological-economic approach to the problem of waste should be flexible [7]. Manufacturers cannot afford to waste the so-called waste products, so processes and technology require continuous monitoring not only for by--products and waste, their toxicity but also the potential for development.

2. The inorganic industry in Poland

In 2009, worldwide chemical industry sales (excluding pharmaceuticals, plastics and rubber) amounted to €1871 billion, 24% of which coincided with the sales of the EU27 chemical industry. In 2004, the EU, which had been the leader in the chemical industry production, was overtaken in the industry rankings by the countries of Asia. The dynamic development of the chemical industry in this region occurred as a result of the increased investment of local and global companies, cheaper raw materials and less restrictive regulations concerning environmental protection (especially in China and the Middle East). Two-thirds of EU27 production is generated by Germany, France, Italy and Great Britain. Among the new EU members, Poland is the largest producer (2.3% of sales) [5,6]. The global financial crisis has not spared the chemical industry in Europe, and that includes Poland. The inorganic industry was among the sectors of the European chemical industry most severely affected by the global crisis. Decline in demand from users of inorganic chemicals has forced a significant reduction in production, and in some cases even plant closures. In 2009, basic inorganic chemicals production recorded an 18.7% annual decrease in output. The year 2010 was a period of economic recovery (Tables 1 and 2) – almost all chemical companies ended the year with a profit. The chemical industry accounts for about 10% of total industry sales. Currently, the production of chemicals is ahead of industrial production, but given the significant decline during the crisis, growth is still unsatisfactory. The development of the inorganic sector strongly correlates with the financial state of its customers and the raw materials and fuel market [5, 6, 8, 9].

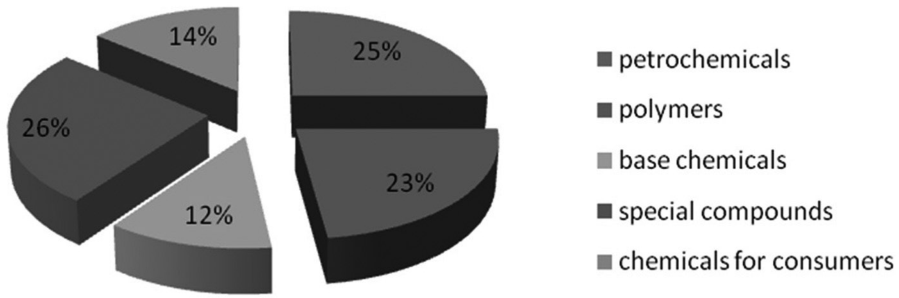

Fig. 2. The structure of EU27 chemical production in 2009, CEFIC [6]

Rys. 2. Struktura produkcji chemicznej UE27 w 2009, za CEFIC [6]

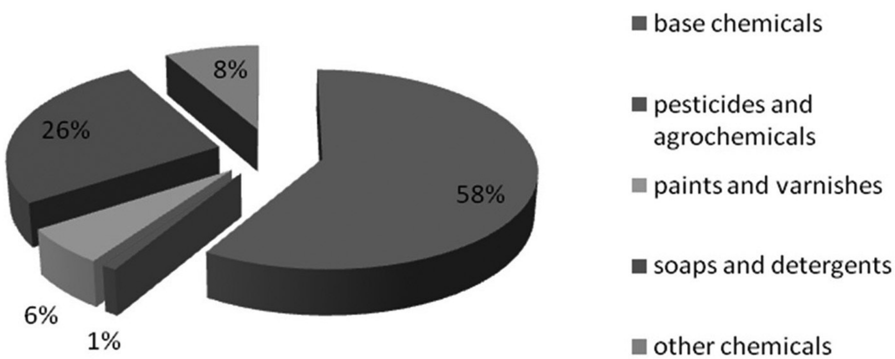

Fig. 3. The structure of chemical production in Poland in 2009, PIPC [6]

Rys. 3. Struktura produkcji chemicznej w Polsce w 2009 r., za PIPC [6]

Table 1

Chemical industry production sales in Poland 2008–2010, in million PLN (GUS (Central Office of Statistics) data)

Branch	2008	2009	2010	Dynamics 2010, 2009 = 100
Manufacturing (Total)	720 694.2	854 900	945 030	109.8
Chemicals and chemical products	37 966.8	36 473.6	419 000	112.0
Pharmaceutical	9 558.8	10 646.7	11 600	106.0
Plastics and rubber products	41 764.8	43 109.4	50 000	115.7

Table 2

Production of major inorganic chemicals in Poland, in thousands of tons (GUS (Central Office of Statistics) data)

No.	Description - production years	2006	2007	2008	2009	2010
1.	Sulphuric acid (calculated as 100%), thousand tons	2131	2224	2020	1460	1684
2.	Caustic soda (calculated as 96%), thousand tons	462	487	409	380	53.2
3.	Anhydrous soda including heavy and raw bicarbonate (calculated as 98%), thousand tons	1119	1132	1140	938	1010
4.	Mineral and chemical fertilizers (in terms of pure component, including multi compound), thousand tons including:					
a)	nitrogen	2601	2830	2558	1919	1630
b)	phosphorus	1714	1833	1715	1503	475
c)	potassium	595	648	536	243	314

3. Waste generated

The Eurostat figures show that in 2006, European Union (EU27) citizens produced almost 3 billion tons of waste. This is equal to over 6 tonnes of waste per capita. Waste comes from many activities: commercial, industrial, agriculture, construction, mining, energy, transport and household. Industrial waste, which accounts for almost half the waste generated by the economic activity, arises from three main industry sectors: mining, manufacturing and the generation and supply of electricity, gas and water vapour. A significant share of this group of waste comes from the extractive industries (in 2006 they accounted for 54.4% in the EU). According to the same information (EU27, 2006), the European production of chemicals, chemical products, fibres, rubber and plastics contributed to around 11% of the industrial waste. The Eurostat data for Poland (2006) shows that about 10% of industrial waste is produced by the above-mentioned group, 66.8% of which is sludge and chemical residue, 5.7% is waste acids, bases and salts and 6.9% is chemical preparation waste. Inorganic waste may account for around 2% of the generated industrial waste in Poland [4]. More detailed data collected on the basis of regional data (irrespective of tonnage) [2] shows that group 06 (inorganic waste) is about 2.6% of industrial waste produced in Poland. The most recent data on the total amount of industrial waste generated in Poland is given in the table below (Tab. 3).

Table 3

The amount of waste generated in Poland, excluding urban waste, based on GUS (Central Office of Statistics) data of total waste produced and regional government data (waste 06)

Year	2003	2004	2005	2006	2007	2008	2009
06 waste generated in Poland, million Mg/year	4.883	3.286	3.387	3.569	3.607	2.908	1.622
Recovery (total), million Mg/year	0.669	0.562	0.508	0.503	0.788	0.670	0.517
Disposal (total), million Mg/year	4.123	2.842	2.880	3.022	2.853	2.193	1.150
Recovery share (total) [%]	13.71	17.10	15.01	14.11	21.87	23.05	31.91
Waste share (total) [%]	84.44	86.49	85.04	84.67	79.10	75.41	70.93

The largest share of the above-mentioned waste group 06 can be attributed to the following types of waste:

06 09 80 phosphogypsum and phosphogypsum slag 06 09 81 (total) 77.98%
06 05 03 sludge from effluent treatment 10.77%
06 11 83 ferric sulphate waste 3.77%
06 01 01* Sulphuric and sulphurous acid 0.03%

Hazardous waste accounted for 3.80% of all code 06 waste. The largest share of this amount was attributed to the following types of waste:

06 01 01*	Sulphuric and sulphurous acid	86.72%
06 02 01*	Calcium hydroxide	4.19%
06 02 04 *	Sodium and potassium hydroxide	3.61%

In 2004–2009, code 06 waste destined for recovery operations accounted for 18–31% of the quantity produced, with 70–80% destined for disposal. Inorganic waste was almost exclusively destined for recovery operation R14 (i.e. the activities leading to the total or partial use of waste, or to the recovery of substances or materials from waste, together with their use) and disposal – D5 (landfilling of hazardous or other non-hazardous waste) and D9 (physicochemical treatment, such as evaporation, drying, calcination, etc.) [1, 2].

Table 4

Group 06 waste recovered and disposed of in relation to the quantity produced in 2004–2008 (based on regional government data)

Waste code	Description of waste	Recoverable amount [%]	Disposal amount [%]
060981	Phosphogypsum mixed with slag, hearth ashes and cauldron dust (excluding cauldron dust mentioned in 10 01 04)	0	100
060980	Phosphogypsum	11.14	78.53
060503	Sludge from effluent treatment other than those mentioned in 06 05 02	97.17	2.45
060101*	Sulphuric and sulphurous acid	52.28	46.01
060399	Waste from the manufacture, preparation, handling and use of salts and their solutions and metallic oxides – not otherwise specified in 0603 Waste	94.97	–
061199	Waste from the production of inorganic pigments and opacifiers	–	99.88
060904	Calcium-based reaction waste other than that mentioned in 06 09 03 and waste 06 09 80	74.02	–
061183	Ferric sulphate waste	4.23	26.42
060201*	Calcium hydroxide	0	100.00

4. The research areas and issues defined for the inorganic waste foresight problem in Poland

Given the state of the industry discussed above as well as recognizing current inorganic waste management, the implementers of the project "Inorganic waste in the chemical industry - technology foresight" identified the areas and problems discussed below. These problems are presented to experts outside the project in the form of Delphi survey questions, and they are the subject of panel discussions. Answers to the questions developed with characteristic foresight methods allow us to prepare several alternative scenarios for the development of inorganic industry and waste management, which will be the end product of the project. The research will be completed in March 2012 with the publication of a final report outlining the development scenarios.

The research is divided into regions (Fig. 4 and Tab. 5). In these areas, the most important issues are defined.

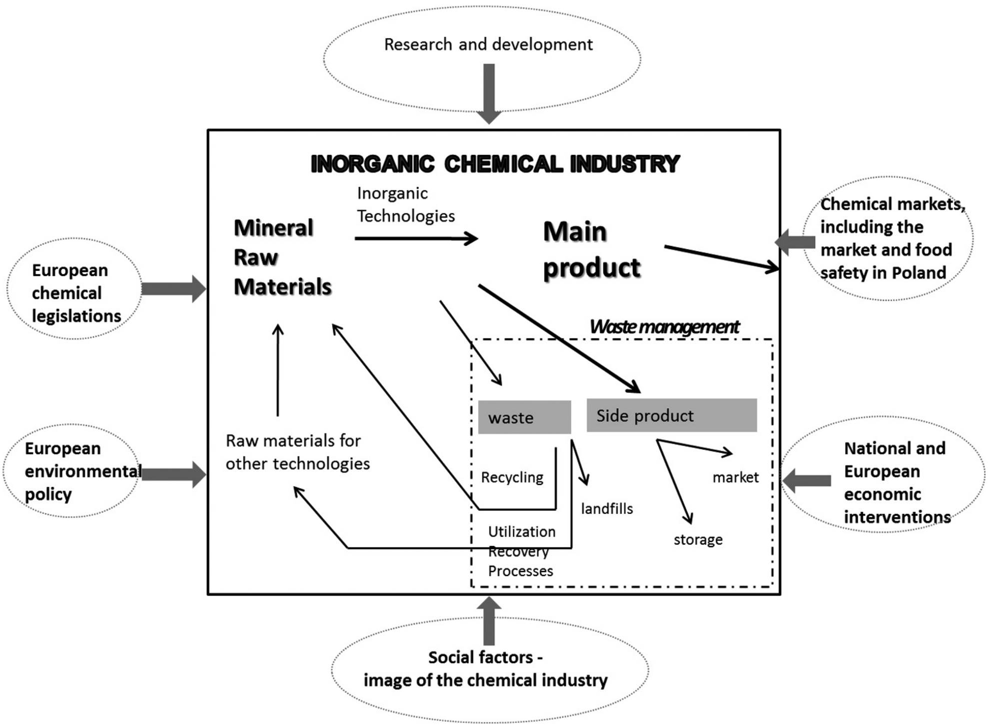

Fig. 4. Research area and areas affecting the subject of research

Rys. 4. Obszar badań i obszary wpływające na obszar badań

Table 5

Defined research areas and issues

I. Area: Policy-ecology
1. Extension of the IPPC Directive – strengthening the role of BAT
2. REACH – the need to register in the system waste recovered in a different manner than simple recycling
3. Climate package – emission limits, costs, limitations
4. Assessment of the impact of technology on the environment – costs and benefits
5. Effects of pollution movement between environmental components
6. Economic intervention: environmental subsidies/charges
7. Agricultural Policy (fertilization, organic farming, subsidies)
II. Area: Economic environment
1. The global crisis/economic cycles
2. The dynamics of demand for inorganic products
3. Market prices/costs – competitiveness
4. Prices of fuels and energy (gas)
5. Competition outside the EU
III. Area: Social Surroundings
1. Acceptance of industrial burden – jobs and the purity of ecological surroundings
2. Waste management at the local and governmental level
3. Ecological awareness of employees and residents
4. Approval for the plant/processes of waste recovery and disposal in the neighbourhood
IV Area: The market
1. Mineral Resources Market
2. Fertilizer market, supply and demand, periodicity
3. Basic inorganic chemicals market
4. Import/export of inorganic technology
5. Cross-field links
V. Area: Waste as products
1. Phosphogypsum – currently the largest non-organic waste (tonnage)
2. Poorly marketable products around sodium
3. Ferrous sulphate/waste from the production of titanium dioxide
4. Sulphuric acid waste
5. Sludge from effluent treatment
6. The dynamics and changes in the weighting structure of the above waste
VI. Area: Key Technologies
1. Concentrated phosphoric acid, phosphatic fertilizers and NPK
2. Soda
3. Titanium dioxide
4. Sulphuric acid, including post-metallurgical
5. Other inorganic technologies
VII Area: Research and development
A. Research related to the processes of recovery and disposal of waste
1. Recovery/recycling of inorganic waste
2. Utilization and reclamation of waste storage
3. Modern separation techniques (e.g. nanofiltration, membrane technology)
B. Research related to complementary products, processes and patterns of consumption
4. Inorganic product biotechnology
5. Nanotechnology
6. Research on increasing the bioavailability of fertilizer compounds
7. Functional equivalents (other compounds used for the same purposes)
8. Technology of specialised low-tonnage products with high added value
C. Research related to reduction in the environmental impact of existing production processes

5. Foresight methodology

The above data can be applied in analytical models, which should allow us to answer the basic research questions formulated in the previous section. The data collected in Delphi research, however, tends to be unreliable as it is difficult to verify experts' answers, and it may represent subjective opinions, motivated by environmental or corporate interests. Also necessary is the simultaneous and consistent use of qualitative information, which is often made only verbally, as well as quantitative models and data. For this reason, information gathered during a single survey is not considered in the theory and practice of foresight to be meaningful. The recognised method is to divide the research into so-called rounds. There are usually two rounds – in the second, the responses from the first round are made available either to everyone participating in the research or to a particular subgroup of participants. The purpose of this is to verify, clarify and refine the information gathered. Further investigation may involve another round of surveys, in which the results obtained so far are discussed and a final opinion is adopted by consensus during the so-called panel discussions with key foresight project experts.

In order for the entire foresight process to be objective, it is necessary to create an appropriate knowledge base, which comprises a system of databases containing heterogeneous information such as time series on the production of key substances that are accompanied by group 06 waste, prices of raw materials, energy, and chemical intermediates used in production processes as well as quantitative and qualitative information on the production technology. An important part of the knowledge base is an expert system allowing on-line updating, extraction and visualization of information contained in the database. Based on the information gathered in the knowledge base, it is possible to perform a series of analyses, whose results will be used to construct scenarios of waste streams until the year 2030. These are mainly:

– A conditional analysis of trends (using trend-impact analysis) including the dependencies of technological processes, prices and production volumes on events such as the introduction of more stringent environmental standards, the emergence of competitive biotechnologies for the production of certain branches of the inorganic chemistry sector such as mineral fertilizers, etc.

– A method of testing mutual linkages and the impact of trends (cross-impact analysis), which will allow cross examination of future trends and events based on mathematical models of discrete event systems [10].

– ASWOTC analysis [3] in several time sections which, in conjunction with the ranking methods, enables the prioritization of actions that ensure the competitiveness of individual industries and facilities and also ensure that appropriate restructuring measures are taken early.

The ranking of key mineral industry technologies will play a supportive role. This will be in the form of a so-called dynamic ranking [10], updated over the planning horizon of the project, i.e. until 2030. These models and methods will be used subsequently to generate basic scenarios, by which we mean sequences of events linked with cause-and-effect dependencies, which constitute the conditions for determining the characteristics of technology evolution processes and supply/demand, described as non-linear trends. After Monte-Carlo simulation and analysis of conditional quantitative forecasts within basic clustering scenarios, it will be possible to isolate three to five principle scenarios describing the key alternatives shaping waste streams in the inorganic chemistry sector until 2030.

The end result will be a report containing the results of the foresight scenario analysis with proposals for companies and institutions interested in implementing the results of the project. The existing practice has shown that the most effective form of applying foresight results to the realities of a particular industrial plant is the so-called technology road-mapping, which is presented in more detail in the article by Skulimowski [11].

6. Conclusions

From the environmental and economic standpoint, waste is a useless product of economic and social development processes and should be managed in a way that is safe for people and the environment. This type of management requires investment, which constitutes an integral part of the cost of manufacturing products. In practice, non-waste business processes hardly ever occur. The priority task is to reduce waste to a minimum, and this includes finding a technology for processing waste substances into useful products. This task goes beyond simple waste management and enters the field of production and service process design [12]. These are the arguments for the implementation of forecasting and foresight projects not only in the area of waste management, but also in production technology development.

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