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WIOLETTA CZARNECKA, ANETA OGONOWSKA*, RENATA KONECZNA**

POSSIBILITIES OF WASTE UTILIZATION – FROM ŚWIĘTOKRZYSKIE REGION – IN CEMENT PRODUCTION

MOŻLIWOŚCI WYKORZYSTANIA ODPADÓW WOJEWÓDZTWA ŚWIĘTOKRZYSKIEGO W PROCESIE PRODUKCJI CEMENTU

S t r e s z c z e n i e

Przemysł cementowy wykorzystuje w procesie produkcyjnym dużą ilość odpadów, które nie znalazły dalszego zastosowania bądź nie nadają się do użycia poza składowaniem. Odpady mogą być wykorzystywane jako surowce do produkcji klinkieru, jako dodatki cementu, a także jako paliwa zastępcze. Odpady są stosowane w celu odzysku energii i surowców z odpadów oraz ich unieszkodliwiania – dotyczy odpadów nieposiadających własności palnych lub surowcowych. Skala zastosowania materiałów odpadowych w procesie produkcji cementu w Polsce odpowiada tendencjom światowego przemysłu cementowego. Podstawowe znaczenie mają granulowany żużel wielkopiecowy i popiół lotny ze spalania węgla kamiennego, stosowane jako dodatek do cementu. Wszystkie polskie cementownie w ostatnich latach przeszły gruntowną modernizację i obecnie są jednymi z najnowocześniejszych instalacji w Europie, gwarantującymi w pełni bezpieczny sposób zagospodarowania odpadów.

Słowa kluczowe: *przemysł cementowy, zarządzanie odpadami, współspalanie*

A b s t r a c t

Cement industry, in a production process, utilises large amounts of waste, which did not find any other application and would have to be stored. Waste can be used as raw materials for clinker production, as cement additives, as well as substitute fuels. Waste is being applied with the purpose of recovery of energy and/or raw materials from waste or for utility purposes – it concerns waste without combustible or raw material properties. The range of waste materials application in the cement production process in Poland corresponds to tendencies existing in the world cement industry. Granulated blast-furnace slag and volatile ash from burning hard, bituminous coal are of basic importance as the cement additive. All Polish cement plants in the last years have undergone thorough modernization and at present they are one of the most modern installations in Europe, ensuring the fully safe way of waste disposal.

Keywords: *cement industry, waste management, co-incineration*

* Mgr Wioletta Czarnecka, mgr Aneta Ogonowska, Urząd Marszałkowski Województwa Świętokrzyskiego w Kielcach.
** Mgr Renata Koneczna, Instytut Gospodarki Surowcami Mineralnymi i Energią PAN, Kraków.

1. Introduction

Cement industry, in a production process, utilises large amounts of waste, which, otherwise, would have to be stored or neutralised with much more expensiveness. Waste can be used as raw materials for clinker production, as cement additives, as well as substitute fuels [1, 2]. The most frequent types of waste used in Poland as alternative raw materials in the Polish cement industry are: volatile ashes, siderite siftings, ferric cinders, blast-furnace slags, carbonaceous slates, iron-bearing additives, siliceous dusts, pyrite cinders, furnace clinker [3].

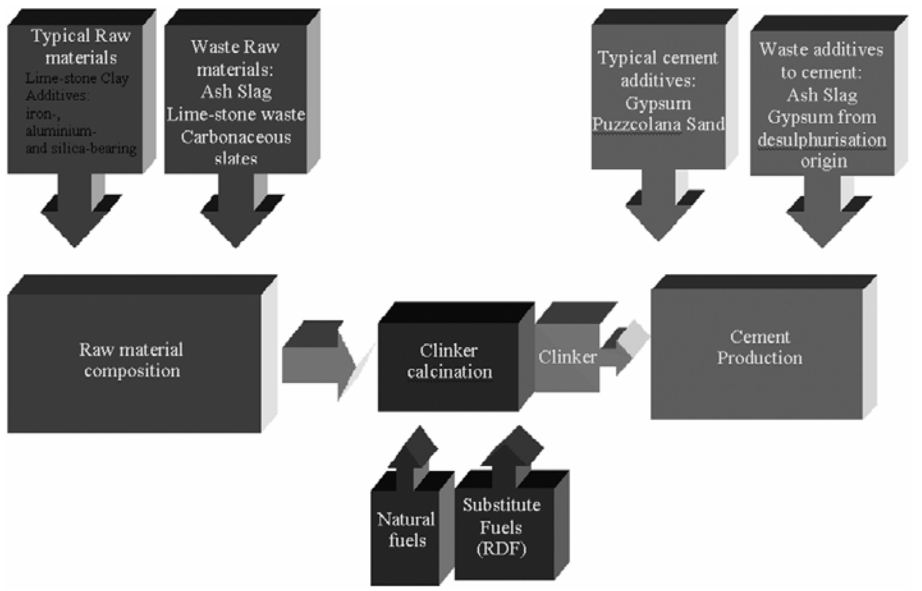


Fig. 1. Waste utilization in cement production process

Rys. 1. Wykorzystanie odpadów w procesie produkcji cementu

2. Methods of waste recovery and its utilization in cement plants

Waste is recovered and neutralised with the following methods (according to the Act on Waste [4]):

R1 – energy recovery from waste – concerns the waste having combustible properties [4a] and the calorific value above 12 MJ/kg. In the case of waste containing below 1% of halogen-organic compounds it is possible to introduce such a substance into the processing system both from the side of the main burner and into the chamber of elevated part of cyclone heat exchanger, whereas waste containing more than 1% of the above mentioned organic halogens may only be given from the side of the main burner.

R 14 – raw materials recovery from waste – concerns waste:

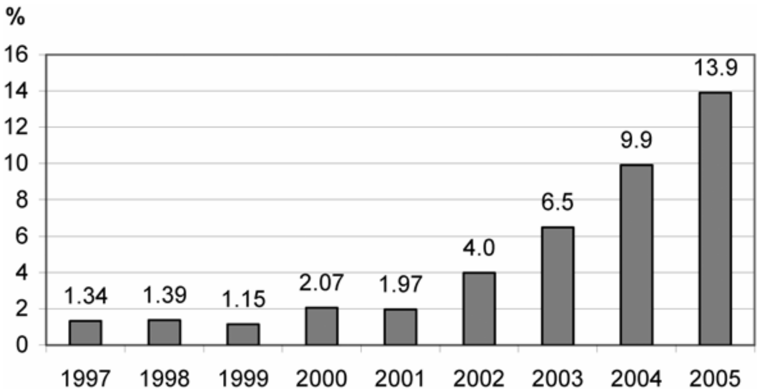
- acting as a substitute for natural raw materials, or
- being carriers of substances needed for the correction of raw material composition, or
- used as additives during the cement production and/or the blends preparation (e.g. slag, cinder, volatile ashes, ashes from fluid boilers).

This waste is transferred to mills of the raw material or of the cement and/or to agitators used for blends preparation.

D10 – thermal neutralising of waste – concerns waste without combustible properties or that which is useless as a raw material or part of it. Such a type of waste may be added to the clinker coolers onto grate, where the pyrolysis process takes place (caused by still comparatively high temperatures); gases are then directed to the kiln, where remaining organic pollutants undergo thermal decomposition and destruction. The amount and the quality of waste subjected to the neutralising stage has to be prepared in such a way, that the finally (after the thermal destruction) remaining solid part of the processed waste does not cause any significant changes in the chemical composition of the produced ceramic clinker, and in turn it does not deteriorate the quality of the final product – cement.

The range of waste materials application in the cement production process in Poland corresponds to tendencies existing in the world cement industry. Granulated blast-furnace slag and volatile ash forming during hard, bituminous coal burning are of basic importance as the cement additive. They are part of hydraulic and pozzolanic mineral additives to the cement, playing an active role in the process of cement hardening and functional traits of the cement matrix. Low costs of gaining these raw materials lead to the improvement of the cement production effectiveness. Apart from **blast-furnace slag** (produced by violent, intense cooling of liquid cinder forming in the blast furnace during iron making by smelting of the iron ore) and **volatile ash** (received by electrostatic or mechanical separation of dusty particles of exhaust fumes from furnaces heated by means of coal dust), the cement industry also uses large amounts of calcium sulphate, applied in the process of cement production as the setting regulator; $CaSO_4$ is usually in a form of raw, waste natural gypsum or chemical one [5].

The area of a particularly important activity of the cement industry – bringing huge benefits for the environment – is the usage of substitute fuels manufactured from waste. The already mentioned benefits for the environment, with respect to waste utilization in the cement industry, should be evaluated in many aspects. It requires underlining a significant role of the cement industry in eliminating waste – quite a big amount on the scale of the year – from the environment and *ipso facto* the reduction of the quantity of the stored waste. On the other hand, applying waste in the process production ensures not only a smaller energy consumption during mining and further processing of natural raw materials, but above all diminishing the share of clinker in cement. This means that less energy consumption for clinker calcinations is required and hence the reduction of gases emission per production unit is obtained. Burning substitute fuels in cement kilns also causes lowering emissions on the global scale, because waste, which is not utilised by the cement industry will be incinerated or stored at some other places – finally contributing to the disadvantageous ecological balance [6, 7].



Source: [3]

Fig. 2. Heat recovery from the Refuse Derived Fuels in Polish cement industry in the years 1997–2005

Rys. 2. Uzysk ciepła z paliw alternatywnych w latach 1997–2005 w polskim przemyśle cementowym

In 2004, according to the information presented by the European Cement Industry, about 17% of fossil fuels consumption was substituted with waste, which constituted about 4 million tons of coal [8]. In addition EURITS – the European Union for Responsible Incineration and Treatment of Special Waste – has published the criteria for waste designed as Refuse Derived Fuels for co-burning in cement kilns. These requirements are presented in Table 1.

Table 1

EURITS criteria for waste designed for co-burning in cement kilns

Parameter	Unit	Value
Calorific value	[MJ/kg]	15
Cl	[%]	0.5
S	[%]	0.4
Br	[%]	0.01
N	[%]	0.7
F	[%]	0.1
Be	[Mg/kg]	1
Hg	[Mg/kg]	2
As, Se, (Te), Cd, Sb	[Mg/kg]	10
Mo	[Mg/kg]	20
V, Cr, Co, Cu, Pb, Mn, Sn	[Mg/kg]	200
Zn	[Mg/kg]	500
Ash (except Ca, Al, Fe, Si)	[%]	5
PCB (total amount acc. to DIN 51527)	[Mg/kg]	0.2

Source: [12]

Furnaces (kilns) for clinker calcinations are very useful units for thermal transformation of waste. EC Directive [9] orders that installations for burning waste ought to be properly designed, equipped, made and exploited, in order to ensure that the monitored temperature of the combustion gases – even under the most disadvantageous conditions of work – amounts to at least 850°C, but these gases should stay there for at least 2 sec. However, if the content of halogen organic compounds in waste to be incinerated – in terms of chlorine – is larger than 1% of the total waste mass, then the minimum temperature of the combustion gases stream should amount to at least 1100°C and residence time of gases (at this temperature) should also amount to at least 2 sec. Furnaces should be equipped with burners, which automatically switch on if the temperature of gases, after final air supply, falls below the acceptable minimum. Similar requirements are arranged for installations of co-burning waste. Furnaces for clinker calcination fulfil all these requirements but some of them are even more rigorous than those required by the regulations mentioned above.

Fuels obtained by waste transformation have been applied in Polish cement plants for over ten years already, but in a very limited range (in 2000 such fuels were applied in 6 cement plants). Out of the six mentioned, two plants belong to Lafarge Cement Poland – one of the largest producers of this mineral binder material all over the world – which was the first company in Poland applying alternative fuels since the beginning of the 1990s of the previous century.

Plants grouped together in Lafarge Cement Poland applying alternative fuels from waste of the cement plant such as "Małogoszcz" and "Kujawy" require the following criteria for waste:
- calorific value – above 14 MJ/kg,
- content of chlorine – below 0.2%,
- content of sulphur – below 2.5%,
- PCB (polychlorinated biphenyls) contents – below 50 ppm,
- content of heavy metals – below 2500 ppm, where:
- mercury – below 10 ppm,
- cadmium, thallium, mercury – below 100 ppm.

Moreover, on the delivery of specific alternative fuel – solid or liquid – apart from the parameters mentioned above, it is required to fulfil additional criteria, i.e.: the point of self--ignition, the content of humidity, the content of ash, the composition and distribution of granulated parts, etc. Such limitations are caused by the influence of technological and ecological factors [10].

3. Ecological and economic advantages of using waste in cement kilns

Ecological advantages of the rotational kilns for clinker calcination are, among others:
- high temperature of the gaseous phase (temperature of flame 1800–2000ºC) guarantees total burning of waste,
- long residual time of combustion gases at the temperature above 1100ºC – length of the rotational kiln guarantees that the combustion gases flow relatively long through the kiln, maintaining the temperature above 1100ºC for a longer period of time,
- frugality of natural fuels – burning the substitute fuels saves natural fuels consumption due to the utilization of waste energy,

– very big thermal capacity, great mass of calcinated clinker and continuous stage of the process guarantee maintenance of the thermal stability of the process and do not influence the necessity of an additional burner installation – feeding of waste automatically stops at the moment of kiln stopping, and the temperature inside that furnace is being maintained still for one hour at the level of about 1000°C,
– elimination of the problem bounded with solid residue elimination after waste incineration – there is no solid waste after incineration,
– alkaline conditions during clinker calcination limit the sour gases emission due to the alkaline reaction existing inside the kiln,
– there are not any significant differences in the emission of gases, whether substitute fuels are applied or not – the measurements of emission showed that no significant differences in the emission of gases appear during the burning of coal only or coal with alternative fuels addition,
– frugality of investments – due to the burning of the substitute fuels in rotational kilns the investment costs connected with the rotational kilns adaptation for burning of waste are disproportionately low in comparison with the expenditure needed for the construction of a waste incineration plant. In incinerators some additional costs connected with the necessity of utilization of waste formed during incineration appear – such a problem does not exist in case of rotational kiln adaptation for clinker calcinations with the addition of waste as a supplementary fuel.

At present on the market there are three groups of fuels [11] available with customary type names PASr, PASi, PAP and the tyres (entire or cut ones):

PASr – solid alternative fuels, ground up – produced from ground up blends of solid waste e.g. fabrics, paper, rubber waste, plastics and the like, with calorific value within the range of 14–18 MJ/kg;

PASi – solid alternative impregnated fuel – produced from liquid combustible waste mixed with thickening agents such as: sawdust, tobacco, cellulose dust, paper and the like, with calorific value within the range of 18–22 MJ/kg;

PAP – liquid alternative fuels – produced by means of homogenization liquid combustible waste, for example: used oils, fractions of fuel oils, solvents, paints, with calorific value within the range of 22–27 MJ/kg;

Worn out tyres – are gained from the market, for the reason of obligations resulting from regulations concerning the obligatory fee of a product – calorific value, which depends on the stage of pollution, is usually assumed as 24–28 MJ/kg.

The high rank of problems connected with waste disposal is reasonable not only due to the generality of their formation, but also from the economical point of view connected with calculable financial benefits resulting from rational economy (recycling of raw materials and the recovery of accumulated energy). Poorly managed economy of waste disposal constitutes the source of pollution of many environmental elements, among others: soil, air, surface and ground waters. With the rational planning there arise huge possibilities of material-resources market creation. Thus the possibility of the energy recovery in kilns used for ceramic clinker calcinations is of great importance.

The current observation showed that industrial furnaces are very useful units for waste recycling (energy recovery) or utilization by thermal transformation into harmless gaseous products. In the burning (sintering) zone of the kiln the material temperature reaches up to 1450°C. The residence time of a material in the high-temperature zone (above 800°C) is over 30 minutes. The highest temperatures during the process of clinker calcinations reach 2000°C – it is the temperature of flame as well as gases in the zone of sintering, in which they stay for about 10 seconds. The temperature of cement clinker leaving the kiln is within the range from 900°C to about 1300°C. So the conditions are very favourable for destruction – even for the most dangerous substances.

The gaseous pollutants arising during the cement production – which are emitted into the atmosphere from furnace systems – come from physical processes and chemical reactions with the participation of raw materials and fuels. In all furnace systems a solid material is moving counter-currently in relation to the flow of combustion gases. This counter-current flow influences on liberation of pollutants, because a circulating fluid bed is formed in the furnace. Many substances, coming from the fuel burning processes or from the transformation of raw materials into clinker stay in the gaseous phase only till the moment when they are absorbed or undergo condensation on the material flowing counter-currently. A high temperature, a relatively long time of gases residence in this temperature, the significant thermal inertia of the furnace and alkaline properties of the batch create favourable conditions for the reduction of substances having acid properties.

These conditions are much more favourable than those in classical incinerators of waste. Moreover, waste ash left after substitute fuel burning enters in the composition of calcinated clinker. So the problem of its neutralization disappears. Thermal conditions existing in furnaces meet all the requirements resulting from appropriate directives of the European Union and the domestic law.

An important argument for burning waste in cement furnaces is the fact that they are already existing and working installations. Almost all of them are equipped with the units which enable supplying fuels obtained from waste (Refuse Derived Fuels) and need only small investments to adapt the new types of fuels or increase their capacity. Even the construction of quite new installations for supplying waste is repeatedly cheaper than the construction of a new waste incineration plant, which requires huge investment expenditure. The resistance of local communities against the incineration plant situation should also be taken into consideration.

4. Alternative fuel versus the renewable energy

According to the Report prepared for the European Commission concerning alternative fuel – both from industrial and municipal waste – the RDF (*Refuse Derived Fuel*) name is applied. Such a fuel is defined as appropriately prepared waste, which meets the user requirements, mainly in the scope of the high calorific value. The Refuse Derived Fuel composition includes combustible fractions of waste, combustible waste from trade and industry, the settlement sewage, dangerous industrial waste, waste of biomass and the like [12].

However, according to the definition presented in [13], the alternative fuel is a waste with code 19 12 10 – i.e. combustible, fragmented waste, with the homogeneous stage of mixing, formed as a result of mixing of waste other than dangerous, with – or without – the participation of solid and/or liquid fuel or biomass which after thermal transformation do not cause any excess of emission standards from the installation of co-burning of waste, determined in the directive of the Ministry of the Environment of 20 December 2005 on emission standards from the installation (Polish National Official Journal Dz. U. 2005, No. 260, item 2181).

Taking advantage of ranking the part of energy obtained during burning/co-burning of the "alternative fuel" as the renewable energy requires realization of many legislative works and technological and organizational actions, i.e.

The competent body of the public administration must determine technical and organizational conditions of credible documenting of the quantitative and energetic participation of the biodegradable fraction of waste included in municipal waste being subject to a thermal transformation in incinerator plants and ranked as renewable energy sources in the energetic balance of the recovery energy in the waste incineration plant by issuing the appropriate executive directive concerning this scope. Actually, there is lack of domestic procedures enabling credible estimation of the so-called participation of a biodegradable fraction in waste.

Enterprises or other manufacturing units which want to carry out the process of the renewable energy generation during the co-burning process have to obtain the status of the waste incinerator/co-incinerator plant, which requires many investment and organizational operations resulting from the domestic legislation in this scope (among other things, the Directive of the Minister of Economy of 21 March 2002 on requirements concerning execution of thermal process of transforming waste (Polish National Official Journal Dz. U. 2002, No. 37, item 339 with further amendments [14]).

Co-burning of waste in cement furnaces is very favourable for the environment, also from the point of view of the pollutants emission. The examinations and analyses carried out so far did not demonstrate an increased impact on the environment by cement plants which implement the process of co-burning fuel obtained from waste. However, in general, a balanced emission of gaseous substances, including the greenhouse gases, is decreasing.

So it is possible to state that in the future cement kilns will still be used for processes of waste thermal transformation, and their significance in this process should systematically increase with the benefit to the environment and the community. Moreover, there is a possibility to partially refinance such investments, among others from the Regional Operating Programme for the Świętokrzyskie Province and from the Operational Programme of the Infrastructure and of the Environment for the years 2007–2013. The mentioned infrastructure operational programme is donated exclusively to large enterprises. Micro, small and medium-size enterprises may be partially refinanced from the Regional Operational Programme. However, one should point here two limitations. In the case of the Preference No. IV beneficiaries are limited to private subjects which execute public services. However, Preference No. I concerns innovative investment (with the maximum help for medium-sized enterprises equal to 3,999,999 PLN) or having a significant influence on an increase in employment and the competitiveness of the enterprise on the local or regional market [15].

The innovative undertakings, for example implementation of the innovative installation for the waste recycling, can also be financed through PO Innovative Economy (investments above 2 million Euro). An essential matter here is the realization of projects showing a high level of innovation. The level of refinancing for the Świętokrzyskie Province amounts to 50 percent for big, 60 percent for medium, 65 percent for small-sized enterprises and as much as 70 percent for micro-entrepreneurs [16].

The possibility to implement the proper method of waste utilization in the production process of cement and donation of such investments will enable, on the one hand, to limit the mountain of waste and reduce the number of landfills, and, on the other hand, to save non-renewable fossil fuels.

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