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POLLUTION REDUCTION THROUGH WASTE CO–PROCESSING IN ROMANIAN CEMENT PLANTS

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Abstract: Waste treatment is a difficult, complex, costly, and time–consuming challenge for companies and municipalities. Some companies offer waste treatment solutions based on a unique industrial process, called co–processing, which ensures the simultaneous recycling and recovery of waste. This industrial–scale application of the principles for the circular economy complies with strict European and international standards and offers the best environmental performance. This paper presents the process of co–processing (pre–treatment and co–incineration) of waste in Romanian cement plants and its advantages.
Keywords: cement plant, waste, co–processing, pollution reduction

1. INTRODUCTION

In the cement industry, there are several technological and economic opportunities to replace natural resources with waste from other industries. They are mainly used as raw materials, as additives to clinker grinding, as well as alternative fuels. Mainly the wastes that can be recovered in the cement industry can be divided into two categories:

≡ non–energetic waste (alternative materials) – which can be used mainly as substitutes for the silico–aluminum component of the raw material mixture, but also partially for limestone, as corrective additives in the raw material mixture or as additives in the grinding of cement as clinker substitute.
≡ energetic waste (alternative fuels) – used to burn the clinker.

The co–processing of energy waste is the heat treatment process, through which all its energy content is recovered, the resulting residue is incorporated into the combustion product, which is the Portland clinker.

By co–processing in cement plants, waste becomes an alternative source of raw materials (recovery by recycling the mineral content of waste) and fuels (recovery by energy recovery of the energy content of waste). Co–processing of waste in the cement industry is a method of waste recovery, recognized at the EU level as one of the best practices for resource efficiency.

Co–processing refers to the simultaneous recycling of mineral materials and energy recovery in a single industrial process: the manufacture of cement. The mineral part of the waste replaces the primary mineral materials (such as limestone, clay, or iron) and the combustible part provides the fuel needed in clinker production (Geocycle, 2016). As a result, 100% of incoming waste is recycled or recovered without generating other waste (Manfredi and Pant, 2011; Queiroz Lamas, 2013; Mutz, and Nandan, 2014; Saveyn et al., 2016). The used technology also ensures the high–performance destruction of toxic components (Karstensen, 2008). Developed 40 years ago in Europe, this recycling process is now widely used and constantly improved worldwide. Cement kilns can use both energies and recycle some of the material content of the waste. In this sense, it is a valuable path from waste to energy (Saveyn et al., 2016).

Approximately 1.3 million tonnes of obsolete tires are sent annually for energy recovery (including co–incineration in cement kilns). On average, 92% of them are sent for energy recovery by co–processing to cement plant kilns. Moreover, a 2015 study shows that 13.5 million tonnes of recovered solid fuel / waste–derived fuel were reused, out of the 17 million tonnes of sorting waste in the EU. Of these, approximately 12 million tons were burned in cement plants and waste incineration plants (Saveyn et al., 2016).

The potential benefits of co–processing technology for solid waste in cement kilns can be estimated by the level of greenhouse gas emissions. Thus, the Ukrainian cement industry has identified the possibility of reducing the consumption of anthracite coal in clinker production up to 262 kt/year and preventing emissions of up to 284 $ktCO_{2eq}$ / year by replacing coal. Also, for the waste management sector, the potential for co–processing was identified by eliminating MSW up to 1,213 kt MSW / year, correlated with the prevention of greenhouse gas emissions of up to 111 $ktCO_{2eq}$ / year in landfills (Kleshchov, 2019).

There are currently considerable differences in the co–processing rate in the EU Member States, with some countries achieving a co–processing rate of only 7%, compared to 95% in others. The EU–28 average is currently 41%. Significant differences were observed between the EU Member States regarding the use of different treatment methods. For example, some Member States had very high recycling rates (Italy and Belgium), while others promoted the use of landfills (Bulgaria, Romania, Greece, Sweden, and Finland).

Increasing the waste processing rate in the EU–28 to 60% will have the following effects:

- reduction of CO_2 emissions by 26.0 million tons;
- processing of 15.7 million tons of waste;
- saving 11.1 million tons of coal equivalent;
- reduction of public investment of 12.2 billion euros in waste and power plants (WTE).

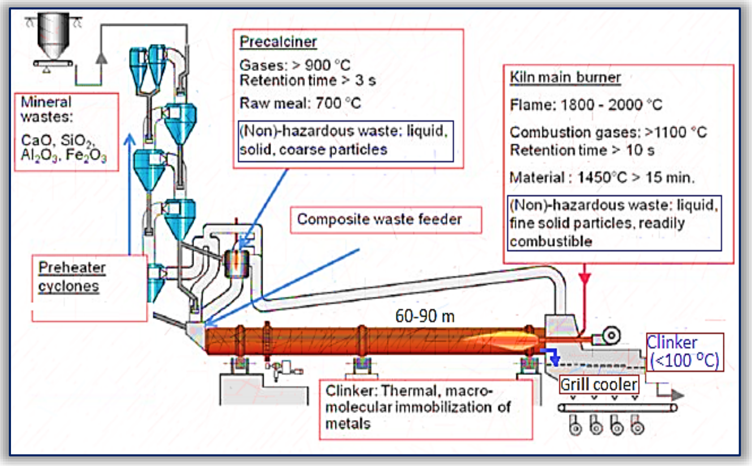

Figure 1 – Simplified scheme of the cooling oven assembly, for obtaining the clinker, with the use of combustible waste (Vijay et. al., 2016)

Co–processing technology is unique because it includes both material recycling and energy recovery in an existing industrial process. These two aspects are the cornerstones of waste management legislation in many parts of the world and in the international context. The benefits of co–processing are widely recognized (Saveyn et al., 2016) and have led to the publication of specific guidelines for co–processing under the United Nations Basel Convention (Basel Conv., 2012).

The studies also tested various options from minimization to recycling and destruction by co–processing in a cement kiln, following the strictest environmental regulations in Ecuador for the management of waste oils.

However, in the co–processing of waste in the cement industry, different pollutants can influence environmental factors and the health of living things in the area. In Europe, such emissions are defined by the European Waste Incineration Directive (2000/76 / EC) and the European Polluting Emissions Register (EPER, 96/61 / EC). About 50 pollutants are covered with air and water emission thresholds (kg/year). It is stated that in Europe, cement kiln emissions to soil and water do not reach the EPER threshold values (Rohland, 2006).

In Romania, although the developments have been significant in the last 10 years and the cement producers have made investments of over 130 million euros in this respect, the alternative energy resources still provide only about 25–30% of the thermal energy needed for the clinker process.

The amount of industrial and municipal waste co–processed in the cement industry in Romania in the period 2004–2020 was approximately 4,000,000 tons, which is the equivalent of municipal waste generated in a year of 24 cities with over 250,000 inhabitants. Thus, about 1,200,000 tons of fossil fuels and as many tons of CO_2 were saved.

2. MATERIALS AND METHODS

Efficient use of natural resources is an important goal of recycling companies. The increase of the ecological efficiency of the production process is achieved especially by:

- co–processing of waste in cement plants,
- reduction of clinker factor (clinker/cement ratio used in the manufacturing process),
- increasing energy efficiency,
- intensive use, in the process of preparation of raw materials, of materials previously stored in the form of waste from the exploitation of limestone quarries. Thus, the limestone quarries related to the factories in Romania have increased their lifespan, reducing the consumption of natural geological reserves. Co–processing of waste in cement plants is a method commonly used worldwide to treat waste safely and simultaneously capitalize on its material and energy content.

Co–processing of waste (sorted industrial or household) under controlled conditions (in terms of quality, environmental protection, and health and safety) has multiple benefits:

- conservation of natural resources – by partially replacing traditional fossil fuels (coal, fuel oil, gas) and traditional raw materials (limestone, clay, marl) with some alternatives,
- indirect reduction of gas emissions that would be generated if the waste were treated by another method (burning in specially built incinerators, landfill),
- medium and long–term reduction of cement production costs (if all costs of collection, transport, pre–treatment, and co–processing are covered by waste generators).

However, not every type of waste can be co–processed in a cement plant. First of all, they are subjected to mandatory physico–chemical analyzes, performed in laboratories equipped with specialized apparatus. In addition to the detailed analyzes, when deciding whether or not a waste is accepted for co–processing, several factors are taken into account to guarantee:

≡ the health and safety of employees, but also of those who live near cement plants,
≡ protection of local environmental factors,
≡ maintaining the quality of the final product,
≡ the operation in good conditions of the cement production process.

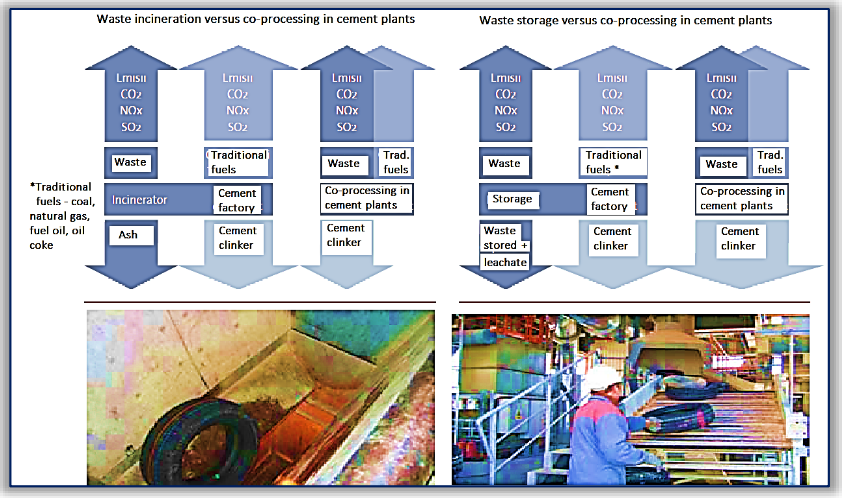

Figure 2 – Incineration and storage compared to co–processing in cement plants

The co–processing, within the cement plants in Romania, has known a continuous evolution, the investments in this field representing over 30 million euros. The development of this activity at cement plants makes it possible to co–process a wide range of waste:

≡ oil (from waste oils and their emulsions to sludge, tar, and contaminated soil),
≡ rubber (including whole worn tires),
≡ plastic, paper, leather, textiles, wood (including sawdust), as such or impregnated/contaminated with various substances, from industrial sources or the sorting of household waste.

Figure 3 – Examples of co–processable waste in cement plants

These wastes are introduced for co–processing as such or pre–treated (eg drying, chopping, shredding, homogenization) to stabilize and optimize their quality. Pre–treatment is, therefore, an integral part of the waste recovery process. Most of the time, the wastes are prepared for co–processing by companies specialized in the field of pretreatment. Some companies that do this, also pre–treat pre–sorted solid waste, collected from waste generators.

Figure 4 – Mixing shredding plant in two successive stages – the shredder

Since 2000, a selective collection system for internally generated waste has been introduced in all locations of cement plants in Romania, to optimize their management and improve the possibilities of recycling and energy recovery of waste. Moreover, specific training and education, and motivation campaigns for their employees to implement proper waste management take place periodically.

Figure 5 – Filter installation with dust removal bags

The Heidelberg cement website it is shown that the use of waste in the production process in the three cement plants of HeidelbergCement Romania complies with the applicable legislation, both at the national level and at the European level. Also, in the last 15 years, only 1% of the total amount of industrial waste processed in their cement plants came from outside Romania.

Also here it is shown that, in the last 10 years, the HeidelbergCement Group has invested only at the European level over 1 billion euros in energy efficiency and emission reduction measures (www.heidelbergcement.ro, 2020). A recycling company has the following activities:

- taking over industrial waste from suppliers,
- collection of sorted municipal waste,
- mechanical treatment of industrial waste,
- mechanical treatment of sorted municipal waste.

The main activity of a co–processing company is the production of fluff – a mixture of sorted, non–hazardous, chopped industrial and municipal waste. It is used as an alternative fuel to the clinker kiln of cement plants. Through its activity, it ensures the preliminary recovery of waste (through their mechanical processing – shredding), and the final recovery – co–incineration is performed in the rotary clinker kiln.

3. RESULTS

The processing of the waste mixture in the recovery plant consists in shredding the mixture in two successive stages (SH1 – shredder 1 and SH2 – shredder 2), extraction of ferrous parts using the metal separator, extraction of inert (heavy) bodies, and using the heavy body separator, storage of the finished product in the bunkers with the rolling floor, from where it is delivered to a clinker oven through a system of conveyor belts.

In this sense, at a waste co–processing company in Romania, the capacity of the mechanical processing plant by shredding non–hazardous solid waste is 200000 t / year (640 t / day, 35 t / hour) waste. The particle size of the shredded waste is 80 mm for the heavy fraction, and that of the main burner (light fraction) is 30 mm.

Waste accepted for mechanical pre–processing is temporarily stored, either in the existing hall on–site – temporary storage area with a capacity of 1800 tons, or in the pre–homogenization hopper where up to 1000 tons of waste for processing can be stored. After processing, the shredded waste is temporarily stored in two compartments of 300 tons of waste each (Geocycle Ro, 2021).

To ensure that all emissions fall within the limits imposed by the Comprehensive Environmental Authorization (AIM), total dust measurements were performed at the waste co–processing company on the following equipment according to Table 1. The integrated environmental permit (AIM) of the monitored co–processing company provides for a total dust concentration in the flue gases of 50 mg / Nm^3. As can be seen from Table 1, all total powder concentrations were within the limits set by the AIM at the time of data collection.

Ferrous and heavy materials extracted from the technological flow, are collected separately and delivered to accredited units for this purpose. The entire installation is equipped with a filter with dust bags.

Waste processing and recovery is an eminently beneficial activity for the environment, otherwise, it should be disposed of in another way, perhaps by storage, and at this time, due to the installation, this waste serves a useful purpose, being transformed into an alternative fuel delivered to cement plants.

Table 1. Dust emission values at the dust removal plant basket in the production hall and at the filter basket in the temporary storage area of the shredded material

Generator source / Pollutant retention equipment	Measurement period	V_{ga} (Nm^3)	V_{gn} (Nm^3)	C_n (mg/Nm^3)	C'_n (mg/Nm^3)	Q_{Vn} (Nm^3/h)	T (ºC)	t_a (ºC)
F1 / Basket of the dust removal installation in the production hall / Bag filter	19.03.2020	0.25227	0.20337	1.58	2.83	18322.7	40.8	19.8
	25.06.2020	0.27059	0.21924	2.36	2.92	20390.3	28.2	23.1
	27.08.2020	0.28187	0.23106	1.29	1.57	20918.9	30.4	24.5
	05.11.2020	0.24974	0.22287	4.18	4.69	22132.6	7.7	5.8
F1 / Filter basket in the temporary storage area of the shredded material / Bag filter	19.03.2020	0.25447	0.20940	1.54	1.87	4188.5	27.8	22.7
	25.06.2020	0.26084	0.21484	1.61	1.95	3900	24.5	22.2
	27.08.2020	0.27451	0.22976	1.81	2.16	4256.9	26.1	25.1
	05.11.2020	0.26979	0.19802	2.28	3.11	5751.6	22.4	6.8

where: V_{ga} – the volume of gas extracted in humid conditions; V_{gn} – the volume of gas extracted in dry conditions; C_n – concentration of dust in humid conditions; C'_n – powder concentration in dry conditions, for a volume of 10% O_2; Q_{Vn} – dry flue gas flow from the pipe at 10% O_2; T – the temperature at the measuring point; t_a – atmospheric temperature on the day (s) of the test.

To ensure that all emissions remain within environmental protection regulations, emissions should ideally be measured and analyzed directly at the kiln draft. This is the only way that allows responsible people to react on time, optimizing those processes and facilities if breaches of limit values occur.

During the "annual emission measurements", the furnace must operate with the average composition of the raw material and the fuel mixture as during the year and the production of clinker. If the furnace needs previous adjustments for conversion to the standard Holcim unit: [mg / m^3], 0 [° C], 1013 [mbar], dry to 10 [%] oxygen for annual emission measurements, then the furnace must be stabilized within 24 hours of adjustment. In tower–cyclone furnaces, emissions of nitrogen oxide (NOx), volatile organic compounds (VOC), benzene (C_6H_6), and heavy metals (excluding mercury) depend heavily on the mode of operation of the furnace (direct or compound operation).

Emissions of sulfur dioxide (SO_2), hydrochloric acid (HCl), ammonia (NH_3), mercury (Hg), and dioxides/furans (PCDD / PCF) depend on the furnace operation. The last compounds must therefore be measured in both modes of operation. If this is not possible then the direct mode is preferred.

The amount of sorted industrial and municipal waste co–processed in the Romanian cement industry in the period 2004–2014 was approximately 2,000,000 tons, the equivalent of municipal waste generated in a year of 24 cities with over 250,000 inhabitants. This saved about 1,200,000 tons of fossil fuels and as many tons of CO_2.

In Europe, approximately 1.1 million tonnes of used tires are recovered and recycled annually in cement kilns.

4. ADVANTAGES OF CO–PROCESSING WASTE

It is understood that all forms of recycling should be encouraged and evaluated to ensure the best environmental, social, and economic results.

Co–processing (pre–treatment and co–incineration) of waste in the cement plant enjoys all the advantages offered by the technological conditions already existing in the cement manufacturing process (SRI, 2016):

- a very high temperature of the flame (2000 °C) and of the material (1450°C),
- the standing time in the oven at temperatures higher than 1100 °C is 5 – 6 sec,
- oxygen–rich atmosphere, which helps complete waste incineration and better efficiency than incinerators,
- the waste in the kiln is in contact with a large flow of alkaline (basic) materials which neutralize the potential acid gases in the combustion and destruction of the waste,
- there is no ash left after co–processing, the minerals being trapped in the clinker matrix,
- the technology of co–processing in cement kilns is accepted by the Basel Convention for the Disposal of Hazardous Wastes,
- reduce global greenhouse gas emissions and conserve fossil fuel resources,
- integrated solutions for waste management and immobilization of toxic and heavy metals.

Adding to these the total recovery of the calorific value of the waste, the lack of other secondary materials (slag, ash) generation that requires subsequent storage, we can say that this method is an ideal solution to solve the waste problem, in complete safety for both the environment. as well as for the quality of our finished product (cement). Co–processing of waste in cement plants proves to be a "win–win" activity for all the factors involved.

For waste generators, it offers:

- the guarantee of total destruction, relatively cheap, in complete safety conditions for the environment,
- closing the products life cycle,
- avoiding environmental problems and related penalties.

For cement producers, it ensures the partial substitution of traditional fuels and raw materials with alternative ones from waste. Active involvement in environmental protection as a Depolluter and provider of environmental services, by avoiding greenhouse gas emissions that could be generated in the case of waste storage or incineration without energy recovery.

However, society and the environment have the greatest benefits, the method resulting in:

- conservation of natural resources: coal, fuel oil, gas, gypsum, limestone, clay, etc.,
- indirect reduction of gas emissions, which would be generated if the waste were treated by storage or incineration in specially designed incinerators,
- reduction of environmental risks (uncontrolled storage, soil, water pollution, etc.),
- avoidance of overcrowding of controlled landfills (dumps),
- improving the image of the environment.

The energetically and/or material recovered wastes that can be processed in cement plants are declared in the integrated environmental permits which are issued by local environmental protection authorities following a detailed process of verification in Technical Commissions (CATs) and publish debate. To each integrated environmental permit the following lists are annexed: the list of wastes with an insignificant impact on the environment that may be accepted for co–incineration and the list of wastes that may be accepted for co–incineration only after prior notification to the environmental protection authority and obtaining the accept for waste coprocessing.

In order to be co–processed in the cement industry, upon entering the factory combustible wastes are subjected to analyzes and determinations in plant laboratories, equipped with state–of–the–art equipment and RENAR accredited for such determinations, regarding:

- the degree of its homogeneity;
- the water and ash content placed in the oven;
- the maximum content of chlorine, sulfur, and alkalis introduced into the furnace;
- granulometry of solid alternative fuels, depending on the type of furnace and the supply point;

- heavy metal and dioxin/furan content (emission limitations);
- the content in elements that affect the quality of the clinker

The conditions imposed by the cement producers aim at:

- failure to affect the quality of the cement in terms of technical performance and environmental protection;
- failure to affect the manufacturing process from an economic, ecological, and occupational safety point of view;
- compliance with the technical, economic, and environmental legal requirements for the placing on the market of the product.

Complementary to recycling, co–processing makes it possible to divert waste from landfills and avoid the generation of greenhouse gases or methane (a greenhouse gas 21 times stronger than CO_2) that would occur after storage. waste (CIROM, 2021).

5. CONCLUSIONS

Energy recovery (co–processing) of waste in the cement industry is a safe process through which over 100 types of waste are transformed, in optimal conditions, into alternative fuel. According to a recent study by Ecofys, 44% of the fuels currently used in the cement industry in Europe are alternative fuels. The study also indicates that the cement industry has the potential to replace up to 60% of traditional fuels with pre–treated waste by 2050. Thus, increasing the co–processing rate of waste to 60% will prevent the European Union, the emission of 26 million tonnes of CO_2 annually.

An important fact must be mentioned, namely that the emissions resulting from the technological process of cement manufacturing are continuously monitored. In addition, periodically a neutral laboratory accredited RENAR, verifies these emissions.

Based on the measurements performed in the cement plants in Romania, it was found that emissions of NOx, CO, HF, HCl, OCD, dioxins, and furans as well as heavy metals are well below the Integrated Environmental Permit limit, which demonstrates the insignificant impact of combustion. waste.

In addition, the Environmental Guard also carries out controls at cement plants, to check the level of parameters, being a total transparency in the communication of the control results.

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