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ASPECTS REGARDING THE ENVIRONMENTAL IMPACT DUE TO THE USE OF ALTERNATIVE FUELS IN CEMENT MANUFACTURING PROCESS

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Abstract: The cement production activity describes a negative environmental impact, which involves the contouring of policies and strategies to minimize it, which can be controlled by an appropriate legislative framework. The paper presents the results of a research on the possibility of minimizing emissions of greenhouse gases (carbon dioxide emissions) from the cement manufacturing process using alternative fuels, namely the opportunity to reduce the consumption of non-renewable resources (fossil fuel).
Keywords: greenhouse gasses, carbon dioxide, alternative fuels, cement

1. INTRODUCTION

For each kilogram of cement, about 0.9 kilograms of CO_2 are emitted into the atmosphere. The production of one cubic meter of concrete (~ 2400 kg) is responsible for emitting ~ 540 kg of CO_2 in the atmosphere (Nisbet M. et al. 2003; Benhelal et al. 2013). In other words, the cement industry is responsible for 5% of global CO_2 emissions from human activities (1.5Gt CO_2) (INCDPM. 2017).

The situation is alarming and it is necessary to reduce greenhouse gas emissions through certain strategies, which can be correlated with the reduction of traditional fuel consumption and the production of clinker with a low limestone content. It is vital that the organizations to adopt an environmental policy that includes their commitment to meeting environmental standards in order to prevent pollution and to embark on a continuous improvement process with the intention of reducing environmental impact (Paraschiv G.. 2016). The legal basis for carrying out the CO_2 emissions monitoring activity is Regulation (EU) No. 601/2012 on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87 / EC of the European Parliament and of the Council. The Regulation offers the possibility to choose from several CO_2 monitoring methodologies, namely: calculation-based approaches, measurement-based approaches, methodology which is not based on levels and combinations of approaches (EUR-LEX. 2017).

The preferred methodology for monitoring CO_2 emissions in cement plants is the standard methodology, which is based on calculations and distinguishes between combustion and process emissions.

Total CO2 Emission = Total Process Emission + Total Combustion Emissions

In 2015, data on waste generation and management in Romania in 2012, was published. Thus, 91.77% of the amount of waste generated in 2012 was stored, only 7.12% was recycled, 0.6% for energy recovery with co-incineration being less than 1%. Romania faces a serious problem with waste management, especially as regards to the need to no longer store waste, the intervention of cement production, where the combustion temperature exceeds 2450°C being beneficial, the advantages being in both ways (Eurostat. 2017).

In a cement factory, the clinkering process is responsible of 60% CO_2 emissions, because the most important reaction in clinker formation is $CaCO_3 \rightarrow CaO + CO_2$ and 40% comes from the combustion process of fuels. Emissions from the process cannot undergo major changes, but there are types of cement in which the addition of secondary matter is higher, in this case, the clinker recipe is adapted, limestone content being a smaller proportion and thus reduced CO_2 emissions from the clinker process (Philip A. Alsop. 2007; Ali et al. 2011).

Conventional fossil fuels used in the cement industry are coal (lignite and anthracite), petroleum coke (the product of refining the fuel oil), heavy fuel oil and natural gas (for tempering the furnace). Alternative fuels, such as used tires, used oils, plastics, solvents, household waste and much more are used as substitutes for fossil fuels. The chemical components of solid fuel ash combine with the raw material and will be fully incorporated into the clinker produced. Therefore, according to the results of laboratory analyses for waste, the chemical composition of ash is taken into account when dosing raw materials.

In the same way as major elements, metals that can be introduced with liquid and solid fuels will be largely incorporated into the clinker structure. Exceptions are made by partly or fully volatile metals in the furnace, such as mercury, talc or cadmium. These elements will condense on the surface of the dust particles that are discharged from the furnace or can, to some extent, be discharged into the atmosphere (mercury) if they are not adequately controlled.

2. MATERIAL AND METHOD

The case study consists in calculating the CO_2 emission reduction, depending on the proportion of alternative fuels used and the fossil fuel substitution rate. Many factors are involved in this process, requiring the involvement of several departments within the factory. Most importantly, the raw material recipe is corrected depending on the input of chemical compounds from the co-incinerated waste. A second major aspect is the principles of combustion technology (Lei et al. 2011). Thus, for a good maintenance of temperatures and co-incineration principles, up to 30% of the total amount of fuels used can be introduced at the cold head of the furnace. In the factory where we conducted the study, it is a rotary clinker oven with a length of 97 m, diameter of 5.8 m and is described by 2 rpm with an injector as shown in Figure 1 (Silviu Opriş. 1999). The technical specifications of the furnace or the injector that were included in the study are presented in table 1.

Figure 1 - Burner

Table 1. Technical data

Production [tons of clinker/year]	1 000,000
Energy consumption [MJ/tons of clinker]	3,300
Energy consumption/year [MJ/tons of clinker]	3 300,000,000
Energy consumption/year [GJ/tons of clinker]	3 300,000

Before using a new type of fuel, a representative sample is analysed by a RENAR accredited laboratory and for the calculation of CO_2 emissions, the net calorific value, the CO_2 emission factor and the proportion of biomass contained are taken into account from the analysis bulletin. The higher the biomass is, the lower the CO2 emissions from the combustion. The calculation formula for CO2 emission is:

CO2 emission [t] = Fuel quantity * Emission factor * Lower calorific value * (100-biomass content)% / 1000

a. Net calorific value (NCV) = the specific amount of energy released as heat when a fuel or material undergoes a complete oxygen-firing process under standard conditions, without taking into account the heat of vaporization of the water formats;
b. Emission factor = average greenhouse gas emission rate relative to the activity data of a source stream assuming that oxidation is complete in the case of combustion and integral conversion for all other chemical reactions

In this study, 5 scenarios are created, depending on the percentage of alternative fuels used, namely: 15%, 30%, 50%, 75%, 95%, taking into account that the cold head of the cement kiln can provide a maximum of 30% of the total mass of fuel and in all 5 cases is kept the percent of 5% for the natural gas. The natural gas is necessary for the tempering times, especially for the beginning of the cement kiln operation, where there must be a perfect climate, without temperature variations.

Table 2. Properties of fuels used (EU. 2012)

Fossil fuels		
Coal		
Net calorific value	GJ / t	25.80
Emission factor	kg CO_2 / GJ	94.60
% Biomass	%	0.00
Petroleum coke		
Net calorific value	GJ / t	32.50
Emission factor	kg CO_2 / GJ	97.50
% Biomass	%	0.00
Natural gas		
Net calorific value	GJ / t	48.00
Emission factor	kg CO_2 / GJ	56.10
% Biomass	%	0.00
Alternative fuels		
Used tires and rubber		
Net calorific value	GJ / t	27.00
Factor Emisie	kg CO_2 / GJ	85.00
% Biomasa	%	27.00
Mixed solid waste		
Net calorific value	GJ / t	15.00
Emission factor	kg CO_2 / GJ	95.00
% Biomass	%	44.00
Agriculture products/waste (husks. shrubs. canes. stumps. etc)		
Net calorific value	GJ / t	27.00
Emission factor	kg CO_2 / GJ	101.00
% Biomass	%	98.00
Wood biomass waste		
Net calorific value	GJ / t	15.600
Emission factor	kg CO_2 / GJ	101.000
% Biomass	%	100.00
Impregnated wood (railway sleepers)		
Net calorific value	GJ / t	20.000
Emission factor	kg CO_2 / GJ	98.000
% Biomass	%	97.00

3. RESULTS

In order to reduce CO_2 emissions, the proportion of biomass existing in fuels should be as efficient as possible and as homogeneous as possible, for optimal furnace operation and complete control of pollutant emissions in atmosphere. The choice of alternative fuels considered in the co-incineration process was made according to their availability in the industrial market:

- case I: 15% used tires and rubber;
- case II: 20% used tires and rubber, 10% mixed solid waste;
- case III: 20% used tires and rubber. 20% mixed solid waste,10% impregnated wood;
- case IV: 20% used tires and rubber, 35% mixed solid waste, 10% impregnated wood, 10% agriculture products/waste;
- case V: 20% used tires and rubber, 35% mixed solid waste, 10% impregnated wood, 15% agriculture products/waste, 15% wood waste.

Table 3. Amount of tones of CO_2 emitted in the atmosphere (5 cases)

CO_2 emissions [t]	Alternative fuels ratio [%]
309.655.5	0
293.256	15
273.458	30
228.591	50
176.590	75
113.626	95

According to these results it can be noticed that the carbon dioxide emission resulting from the combustion process is significantly reduced as the rate of substitution of fossil fuels increases.

Based on these results, it is graphically plotted the carbon dioxide emission reduction trend, which is inversely proportional to the use of alternative fuels for the raw material combustion process.

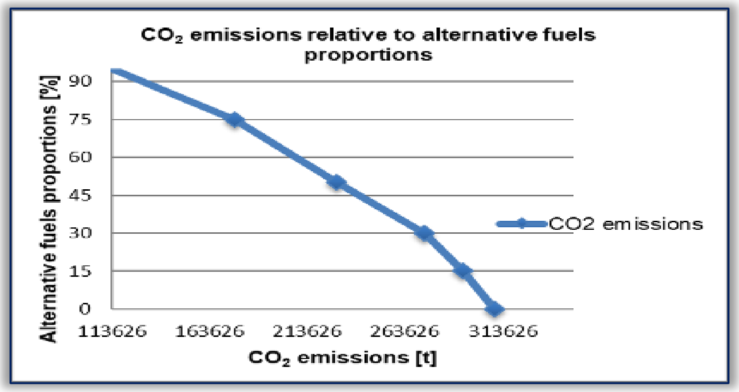

Figure 2 – Graphic representation of carbon dioxide emissions at different proportions of alternative fuels

Figure 3 shows the CO_2 emissions avoided, reported with the original case, where 100% fossil fuels are used. It should be noted, that only carbon dioxide emissions from the combustion process involved in cement manufacture, are specified here and not the process carbon dioxide emissions, which depends on raw material.

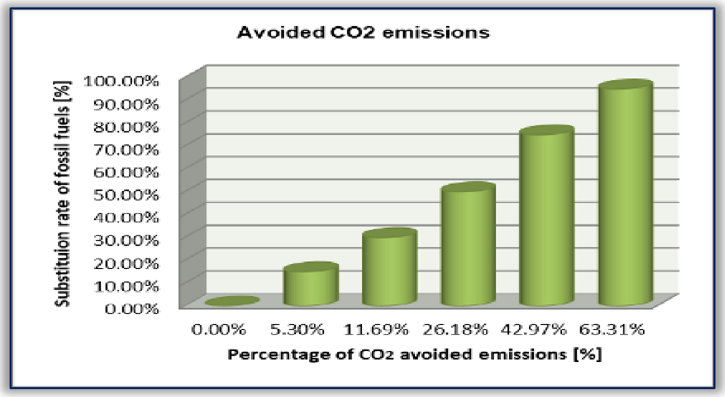

Figure 3 – Carbon dioxide emissions avoided when using alternative fuels

3. CONCLUSIONS

In cement factories, greenhouse emissions, respectively carbon dioxide emissions come from the actual process of manufacturing the cement clinker and the combustion process. Process emissions are very difficult to minimize, because there are not many available alternative raw material resources. But in this study, it is figured that the CO_2 emissions that result from combustion can be reduced by 63% compared to an initial case where only fossil fuels are used. Thus, the notion of co-incineration of waste, substitution of alternative fossil fuels is involved in the process.

The alternative fuels used in this study are: used tires and rubber, mixed solid waste, agricultural products/waste (shells, tiles, wood, sapwood etc.), waste wood, impregnated wood. The alternative fuels used in the case study were chosen on the basis of statistical data suggesting their optimal market presence. Used tires and rubber are introduced into the process at the cold head of the cement kiln up to a maximum of 30% to maintain the thermal equilibrium necessary to create the optimal reaction conditions of the compounds. Mixed solid waste, called fluff, is municipal waste that is introduced through the burner, like the other fuels, but each in its own way (figure 1).

It is also noted, according to the research in this paper that in the optimal achievable case with a 50% fossil fuel substitution rate, conservation of non-renewable materials, respectively fossil fuel consumption reductions are of 39.5% for coal and 48.5% for coke oil, having a positive impact on the environment.

In order to target the use of alternative fuels in the largest proportion in cement factories and to obtain the quantities and the qualities of waste that are desirable for co-incineration, it is important to raise public awareness of selective waste collection.

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