

# Evaluation of environmental impact of cement production in Algeria using life cycle assessment

**S. Boughrara, M. Chedri, K. Louhab\***

Food Technology Research Laboratory, University of Boumerdes, 35000 - Boumerdes, Algeria

\*E-mail address: louhab\_ka@yahoo.fr

## ABSTRACT

The aim of this study is the use of Life Cycle Assessment, to evaluate the impact generated by cement manufactory situated in Sour EL Ghodzlane town in Algeria country, which use the dry process to produce cement Portland.

The LCA method is used for compiling and examining the inputs and outputs of energy, raw material and environmental impacts directly attributable to the manufacture and functioning of a product throughout its life. It is also used to determine element and energy contributing to each impact evaluated.

Potentials impacts are evaluated using the SimaProV.7.1 software and IMPACT2000+ method in this study.

**Keyword:** Life Cycle Assessment; SimaPro.7.1; Impact 2000+; cement Portland; dry process

## 1. INTRODUCTION

Life cycle assessment (LCA) is an important tool used to evaluate and identify the environmental impacts related to a product, service or system from a holistic standpoint that incorporates all known potential environmental impacts and follows the product, service or system from cradle to grave. It is used to understand total energy consumption, identifying energy saving opportunities, and informing decision-makers.

The LCA method has described in the ISO standards 14040 and 14044. It has developed quickly during the 1990s and has reached a definite level of harmonization and standardization. An LCA study consists of four phases: goal and scope definition, inventory analysis, impacts assessment and interpretation [1].

The LCA of a Portland cement concrete road takes into a count the raw materials and energy used in making the cement as well as the emissions from the cement manufacturing process. It includes the energy and resources consumed in mixing, transporting and the environmental consequences [2].

Regarding to the LCA of the cement industry, Huntzinger and al. [3] describes that the production of cement involves the consumption of large quantities of raw materials, energy and heat. The manufacturing process is very complex, involving a large number of materials, pyro processing (wet and dry kiln, preheating...), and fuel sources.

### **1.1. Cement manufacturing process**

Raw materials should be mixed precisely to manufacture the cement. The cement clinker requires appropriate amount of compositions of the elements calcium, silicon, aluminum and iron. All these raw materials together with the fuel as an energy consumption must be combined to form the typical clinker composition [4].

In rotary kiln, the raw materials are calcined at temperature varying between 700 C° and 900°C, which is a combination of alumina, ferric oxide and silica with lime. Between 900-1200°C, there is formation of clinker. The clinkerisation process is following by the cooling stage.

## **2. MATERIAL AND METHODS**

### **2.1. Life cycle assessment methodology**

Life cycle assessment (LCA) is a systematic way of evaluating the environmental impacts arising from resources depletion and process emissions associated with a product or service [2]. It is a method of evaluation used to assess the environmental impacts of technologies from “cradle to grave” .it has the ability to evaluate the materials and energy efficiency of a system, and to identify pollution. It consider the environmental impact of a product during its life cycle: starting with raw material acquisition, through production and use and final disposal.

### **2.2. Goal and scope, functional unit and system boundaries**

The goal of the present study is to assess and the environmental performance of cement manufacturing by dry process. The model focuses on all steps or stages of cement production (blinding and grinding of clinker and addition of mineral components to produce cement). The functional unit of analysis in this study is the production of one ton of cement.

### **2.3. Data quality**

The study is based on the process data supplied by cement production in Algerian manufactories (SOUR ELGHOZLANE using dry process). Data used for this study is based on data records from the plants. In this study, we have used the SimaPro7.1 software to evaluate the environmental impact of inventory aspects using IMPACT 2000+ method Inventory data for raw materials and electricity and heat generated by fuel (natural gas in this case) is obtained from those factories and from SimaPro.7, software databases (table 1-show raw materials and energy resources used in this factory).

**Table 1.** Inventory of dry process of cement production.

Compound	Quantity	unit
Iron	0,02	Ton/Ton cement
Sand	0,06	Ton/Ton cement
Limestone	1,36	Ton/Ton cement
clay	0,10	Ton/Ton cement
Clinker	0.96	Ton/Ton cement
gypsum	0,05	Ton/Ton cement
tuff	0,07	Ton/Ton cement
Electricity	106.13	KWh/Ton cement
Natural gaz	100.13	M <sup>3</sup> /ton cement
gas-oil	1.64	L/ Ton cement
oil	1.09	L/Ton cement
Grease	0.13	Kg/ Ton cement
Water	0.33	M <sup>3</sup> / Ton cement
CO	1,85	Kg/ Ton cement
NO <sub>x</sub>	0,51	Kg/ Ton cement
Particule	0,1	Kg/ Ton cement
CO <sub>2</sub>	766	Kg/ Ton cement

## 2.4. Impacts assessment

The impacts considered in this study are shown in table 2:

- Global warming expressed on Eq kg CO<sub>2</sub>
- Aquatic eutrophication expressed on eq kg PO<sub>4</sub><sup>-3</sup>
- Aquatic acidification expressed on Eqkg SO<sub>2</sub>
- Terrestrial acid/nitrification expressed on Eq.kg SO<sub>2</sub>)
- Respiratory organic expressed on Eq.kgC<sub>2</sub>H<sub>4</sub>
- Ozone layer depletion expressed on Eq.kgCFC-11
- Respiratory inorganic expressed on Eq.KgPM2.5)
- Carcinogen expressed on Eq.kgC<sub>2</sub>H<sub>3</sub>Cl

**Table 2.** Damages categories and impacts categories assessed.

<i>Damage categories</i>							
<i>Humanhealth (DALY)</i>	<i>Ecosystem quality (PDF*m2*yr)</i>		<i>Climate change (Eq Kg CO<sub>2</sub>)</i>		<i>Ressources (MJ Primaire)</i>		
<i>1,445 E-7</i>	<i>89.7 E-4</i>		<i>0,882087</i>		<i>5,77</i>		
<i>Impacts categories</i>							
<i>Carcinogen Eq.kgC<sub>2</sub>H<sub>3</sub>Cl</i>	<i>Respiratory inorganic Eq.KgPM2.5</i>	<i>Ozone layer depletion Eq.kgCFC-11</i>	<i>Respiratory organic Eq.kgC<sub>2</sub>H<sub>4</sub></i>	<i>Terrestrial acid/nutr Eq.kg SO<sub>2</sub></i>	<i>Aquatic acidification eqkg SO<sub>2</sub></i>	<i>Aquatic eutrophication Eq.kg PO<sub>4</sub><sup>-3</sup></i>	<i>Global warming Eq.kgCO<sub>2</sub></i>
<i>13.41 E-4</i>	<i>19.93 E-5</i>	<i>7,44 E-9</i>	<i>4,92 E-5</i>	<i>57.06E-4</i>	<i>8.67E-4</i>	<i>7,86 E-7</i>	<i>0,882</i>

**Table 3.** Contribution of energy to impact.

<i>Energy Categories</i>	<i>Naturel gaz</i>	<i>Electricity</i>	<i>Diesel</i>
<i>Damage categories</i>			
<i>Humanhealth (DALY)</i>	<i>1,538E-8</i>	<i>1,946E-8</i>	<i>1,131E-9</i>
<i>Ecosystem quality (PDF*m2*yr)</i>	<i>14.468E-4</i>	<i>29.833E-4</i>	<i>6,218E-5</i>
<i>Climate change (Eq Kg CO<sub>2</sub>)</i>	<i>29.615E-3</i>	<i>82.846E-3</i>	<i>0,0007207377</i>
<i>Ressources (MJ Primaire)</i>	<i>4,671</i>	<i>1,007</i>	<i>92.434E-3</i>
<i>Impact categories</i>			
<i>Carcinogène (Eq.kgC<sub>2</sub>H<sub>3</sub>Cl)</i>	<i>37.926E-5</i>	<i>82.5 E-5</i>	
<i>Respiratory inorganic (Eq.KgPM2.5)</i>	<i>1,994E-5</i>	<i>2,344E-5</i>	
<i>Ozone layer depletion (Eq.kgCFC-11)</i>	<i>2,113E-9</i>	<i>1,885E-10</i>	
<i>Respiratory organic (Eq.kgC<sub>2</sub>H<sub>4</sub>)</i>	<i>3,145E-5</i>	<i>9,286E-6</i>	
<i>Terrestrial acid/nutri (Eq.kg SO<sub>2</sub>)</i>	<i>47.501E-5</i>	<i>89.626E-5</i>	
<i>Aquatic acidification (Eq.kg SO<sub>2</sub>)</i>	<i>17.448E -5</i>	<i>13.892E-5</i>	
<i>Global warming (Eq.kg CO<sub>2</sub>)</i>	<i>29.615E-3</i>	<i>82.846E-3</i>	

### 3. RESULTS AND DISCUSSION

Table 2 shows all damage categories and impact categories generated by dry process, in this evaluation, we have assessed four damage: human health, ecosystem quality, climate change and resources. Each damage has its impact category: for example damage human health, has two impact categories: carcinogen and respiratory inorganic. It is observed that resources cause major damage, it has an effect on global warming, aquatic eutrophication, and climate change.

Damage of resources is the greatest, it generates two impact categories; global warming at 0.882 eq kg CO<sub>2</sub>, and aquatic eutrophication at 7.86 E -7 Eq.kg PO<sub>4</sub><sup>-3</sup>, that's result from using resource such as natural gas as source of heat necessary to clinkerisation and process. This process is followed by high quantity of gases emitted as CO<sub>2</sub>, SO<sub>2</sub>, and NO<sub>x</sub>, which are the results of combustion process.

**Table 4.** Contribution of energy to impacts categories.

<i>Consumption Catégories</i>	<i>Natural gaz</i>	<i>Electricity</i>
<i>Carcinogène (Eq.kgC<sub>2</sub>H<sub>3</sub>Cl)</i>	<i>28.5%</i>	<i>61.5%</i>
<i>Respiratory inorganic (Eq.KgPM2.5)</i>	<i>11.5%</i>	<i>11%</i>
<i>Ozone layer depletion (Eq.kgCFC-11)</i>	<i>12%</i>	<i>2.5%</i>
<i>Respiratory organic (Eq.kgC<sub>2</sub>H<sub>4</sub>)</i>	<i>62.5%</i>	<i>18.5%</i>
<i>Terrestrial acid/nutri (Eq.kg SO<sub>2</sub>)</i>	<i>85%</i>	<i>15%</i>
<i>Aquatic acidification (Eq.kg SO<sub>2</sub>)</i>	<i>20.5%</i>	<i>15.5%</i>
<i>Global warming (Eq.kgCO<sub>2</sub>)</i>	<i>3.2%</i>	<i>9%</i>

Table 4 shows contribution of energy; natural gas and electricity to each impact category. It has observed that, natural gas at 85% to terrestrial acidification and nitrification

and at 62.5% to respiratory organic which is due to gaz emission  $\text{NO}_x$ ,  $\text{CO}_2$  and  $\text{SO}_2$ . Figure 1 resumes the contribution of energy to impacts categories.

A study done by Ahmed Abdelmotaleb and al [5], on effect of fuel on life cycle of Egyptian cement industry: environmental impact assessment approach, results show that the decision of replacing the existing used fuels in cement industry by coal will carry an additional burden on the environment approximately by 20%. Global warming and respiratory inorganic recorded highly negative impacts of 20% and 25% respectively when using the coal compared with other fuels type. The damage human health is dominated when using the coal with a relative contribution of 30%.

In our study, for human health damage, carcinogen and respiratory inorganic, natural gaz and electricity contribute respectably at (28.5%, 61.5%) and (11.5% 11%). This damage is posed by contamination air, sol and vegetation. Marta Schuhmacher and al [6] in their study show that the incremental risk of mortality /morbidity produced by PM, and  $\text{SO}_2$ ,  $\text{NO}_2$ , does not mean any important additional health risk for the population living in the area under evaluation. The highest annual incremental risk corresponded to particles', with mean concentrations of  $4.6 \cdot 10^{-5}$  and  $3.8 \cdot 10^{-4}$  for chronic mortality and morbidity, respectively

( $1.6 \cdot 10^{-4}$  and  $1.3 \cdot 10^{-3}$ ). For a population of 80.976 inhabitants, annual increments of 37 subjects have been estimated to show health effects due to emission from plant. In relation to PCDD/ Fs, the inhalation cancer risk in this case is for maximum concentration.

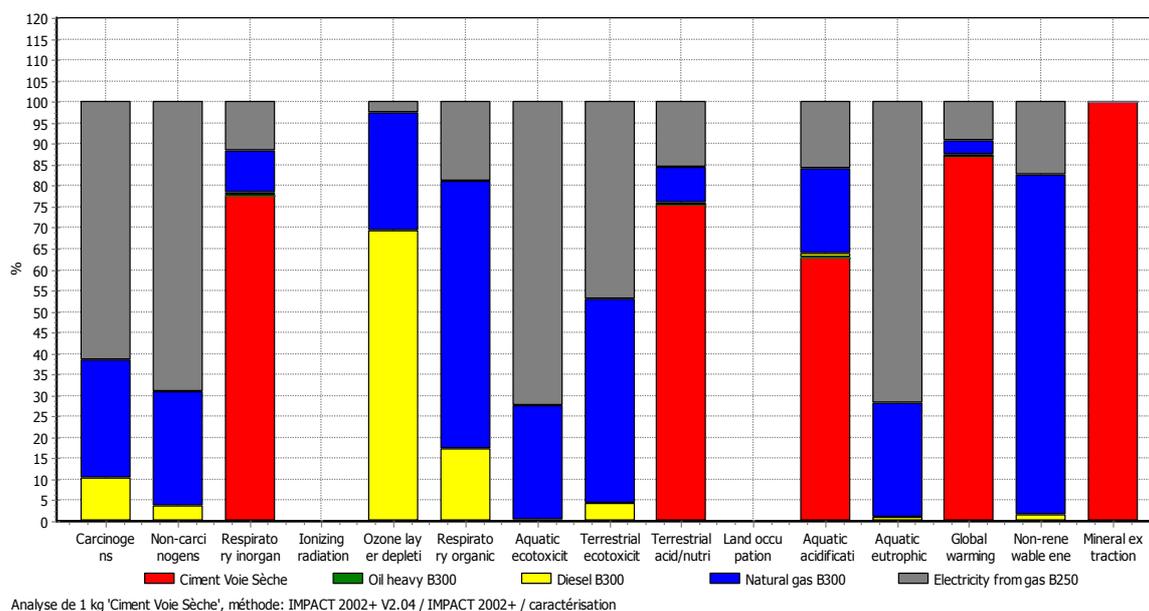


Figure 1. Contribution of energy to impacts categories.

#### 4. CONCLUSION

Life cycle assessment is a useful tool for evaluating the environmental impact generated by system, product or service. In this case we have used LCA in order to determine and evaluate the impacts generated by cement production in Algeria, using dry process, with this

tool and using SimaPro7.1 and IMPACT 2000+, we have assessed all damages categories with their impacts categories, and contribution of energy used to those impacts.

In the present study, natural gas and electricity contribute, to each impact category such as carcinogen, respiratory organic, global warming... because during the process of production, it has generated a most quantity of gases and particles emitted through atmosphere.

So, we can make intervention in order to reduce the impact categories, by replacing energy used or minimization of energy and raw material consumption. So this tool helps to make decision in politic of environmental management.

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