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Enviornmental Impact of Algerian Cement Factories on Fauna and Flora

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The aim of this study is to evaluate the environmental impact of atmospheric emission of two kinds of cement portland processes in the Algerian factories on fauna and flora. The first uses the dry process and is located in a rural area (Sour El Ghozlane) and second is in an urban area (Rais Hamidou) and uses the wet process. To evaluate the atmospheric impacts generated by the cement factories, life cycle assessment approach is applied using Simparo 7.1 software and EDIP method. A comparative study of the impacts evaluated for these processes and the contribution of the compound for all impact categories were determined.

Keywords: Life cycle assessment, Cement production, Dry rotary kiln, Wet rotary kiln.

INTRODUCTION

The studies on the potential impacts of cement production that occur in our planet are among the biggest problems. The portland cement manufacturing industry is under a close scrutiny, these days because of a large volume of CO_2 emitted during manufacturing of portland cement clinker. Some estimates put the cement industry total as high as 5 % of global anthropogenic CO_2 emission [1].

In addition, cement manufacturing process produces millions of tons of the waste product cement kiln dust each year contributing to pollution and respiratory health risks. It is one of the major contributors of greenhouse gase (GHG) emissions, especially CO_2 emission that consumes approximately 12-15 % of total industrial energy usage [2]. Recently, one of the most important goals of the global environmental agenda is to reduce emissions to protect the earth climate. For globally significant products such as cement, environmental life cycle assessment is a valuable tool to improve our understanding of environmental risks posed by life stages of a product. Moreover, it allows cement producers to optimize the manufacturing process by reducing adverse environmental impacts. The concept of environmental life cycle assessment was developed on the basis of the idea of comprehensive environmental assessments of products.

Construction system description: There are two major types of cement kilns, those receive dry feed and others receive slurred feed. In the wet kiln process, the feed enters as a slurry with a moisture content of 30-40 % [3]. In another case, the raw materials are mixed with 25-50 % of water to make slurry to be fed to the kiln. Here the raw mix dehydrates, calcines and undergoes the clinkering reaction [4].

In order to evaluate the environmental impact of the atmospheric emission, of two kinds of cement process, we have used the life cycle assessment approach to make a comparative study of dry and wet process and identify the contribution of an element to all impact categories using SimaPro.7 Software and EDIP 2003 method.

Dry process rotary kiln: In this case, we use the dry rotary kiln system in Sour El Ghozlane plant which was constructed in 1982, in an area of 389.907 m^2 and situated in a rural region at 31 km of Bouira town, with a capacity of 3,000 tons of clinker/day and 1,000,000 tons of cement/year. Traditional portland cement is composed primarily of clinker that has the composition as indicated in Table-1 and gypsum as additive.

TABLE-1
RAW MATERIALS COMPOSITION OF CLINKER

Raw materials	Sources	Mass (%)
Lime	Limestone, shells, chalk	60-67
Silica	Sand, fly ash	17-25
Alumina	Clay, shale, fly ash	2-8
Iron oxide	Iron ore	0-6

The raw materials are carried or mined and transported into the manufacturing facility to be crushed and milled into a fine powder before entering a preheater and eventually into a large rotary kiln where materials reach a temperature of more than 1400 °C [5]. The clinker or the kiln product is cooled and the excess heat is typically routed back to the preheater units.

Prior to packaging, gypsum is added to the clinker to regulate the setting time. The final product is a very fine-grained mixture (90 % ≈ 10 μ) known as Portland cement. Within the preheated and kiln systems, particulate control devices are used to capture fine particulates of unburnt and partially burnt raw material that mixed in the combustion gases. Fig. 1 provides a flow diagram of the general cement manufacturing process and the associated inputs and emissions during various steps of production process.

The raw material passes through the rotary kiln towards the flame. In the calcination zone 700-900 °C, calcination as well as an initial combination of alumina, ferric oxide and silica with lime. Between 900-1200 °C, the clinker component $CaOSiO_2$ forms in a subsequent zone in which temperature raises to1250 °C. During cooling stage, molten $CaOAl_2O_3$ is formed and if the cooling is slow, it may dissolve back into the liquid phase and a secondary liquid appears. The fast cooling product (clinker) enables heat recovery to form the clinker and to improve the product quality [6,7].

Wet process rotary kiln: In this case, a cement manufacturing plant situated in urban region (Rais Hamidou) was constructed by Lafarge in 1914. The plant is situated at 7 km of west of Algeria and its production capacity is around 350,000 tons/year.

Comparing to a dry process kiln of the same diameter, a wet process kiln needs an additional zone to drive off the water present in the kiln feed. In this case water is added at 32-35 %. The advantages of a wet process kiln are that feed can be blended more uniformly and dust losses are smaller. The major disadvantage is the increased fuel consumption in order to evaporate water present in the feed,

The number of raw materials required by any plant depends on the composition of these materials and the type of cement being produced. From the several raw materials, kiln feed is blended so that it may typically consist of 64 % CaO, 22 % SiO_2, 4.5 % Al_2O_3, 3 % Fe_2O_3. The composition varies for different types of Portland cement. Other minor constituents such as MgO, SO_3 and alkalis make up the balance. The raw feed is then transferred to grinding mills where water is introduced to make slurry, which is fed into the kiln. Here raw feed, as it moves through the kiln, undergoes three major changes. First, dehydration, where water is evaporated. Second, calcination where CO_2 is evolved from limestone and third, clinkering where the silicates, aluminates and ferrites are combined. These three processes occur in the ranges 40-212 °C, 212-1800 °C, 1800-2650 °C, respectively.

An alarming aspect of cement manufacturing is that only slightly more than 30 % of the energy input is used to produce clinker, while the remaining 70 % is lost due to radiation through the kiln shell, evaporation of water and non-recoverable heat in the kiln exit gases. It is primarily this last energy loss, in exit gases, that can be minimized by effective control [3].

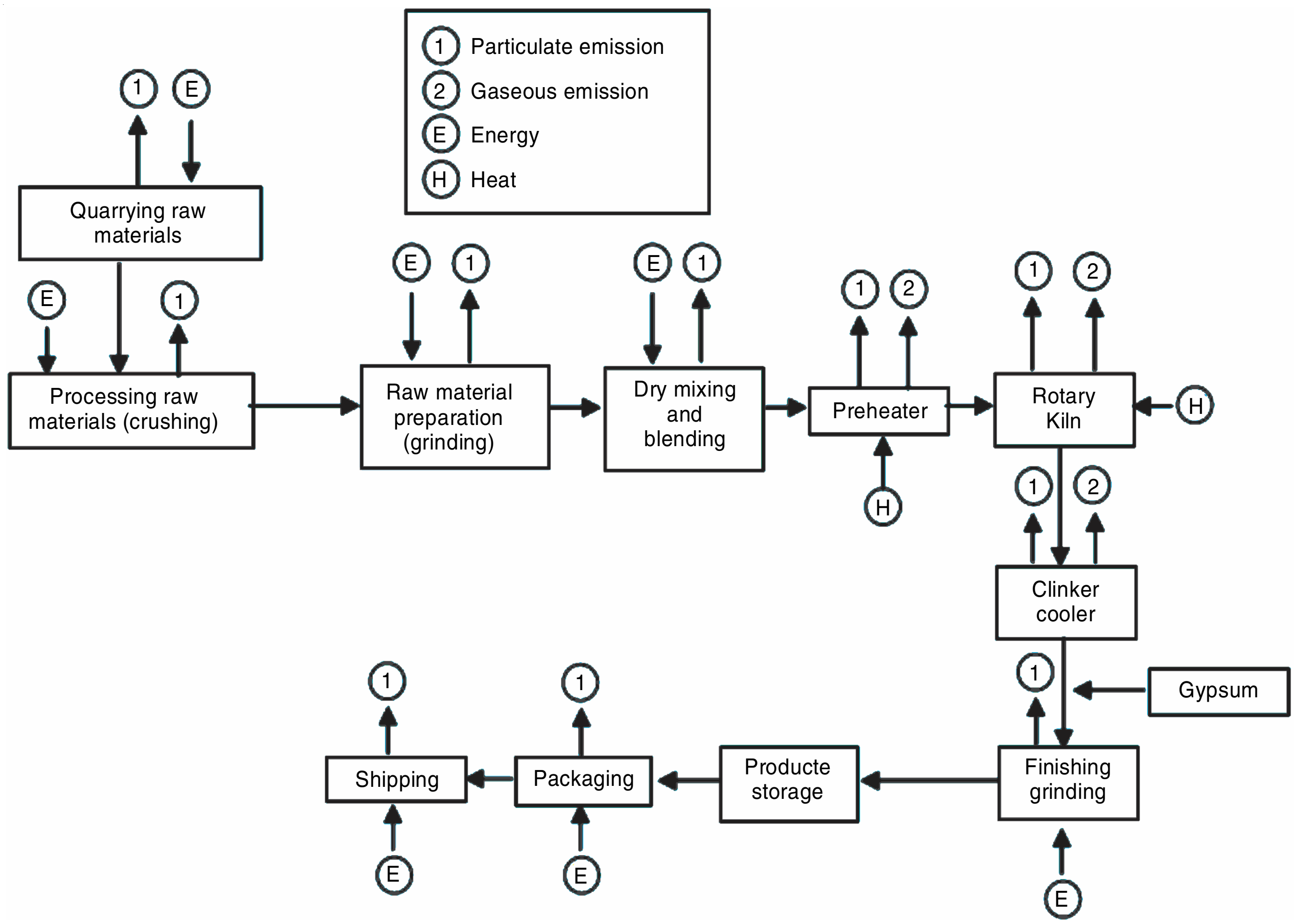

Fig. 1.

EXPERIMENTAL

Life cycle assessment methodology: Life cycle assessment (LCA) is a method of evaluation used to assess the environmental impacts of technologies from "cradle to grave" and may be performed on both products and processes. There are several benefits of life cycle assessment; it has the ability to evaluate the materials and energy efficiency of a system, to identify pollution shifts between operations and producing benchmarks for improvement.

Life cycle assessment has been proved to be a potential tool to evaluate the improvement of industrial processes, it used to avoid sub-optimization in the development of more environmental adapted cement and concrete product and manufacturing processes. Furthermore, life cycle assessment is a suitable tool for assessing environmental impacts of clinker production and its associated supply chains.

The goal of the current study is to assess and compare the environmental performance of two different processes of cement production. The model focuses on clinker production in the cement kiln including blending and grinding of clinker and additional mineral components to produce cement. The functional unit of analysis in this study is the production of one ton of cement.

RESULTS AND DISCUSSION

Data quality: The study is based on the process data supplied by Algerian cement manufactories (Rais Hamidou for wet process and Sour Elghozlane for dry process).

The life cycle assessment SimaPro7.1 is used to evaluate the environmental impact of inventory aspects and to assess and compare two life cycle assessments of two different types of production processes of cement.

Inventory data for raw materials *i.e.*, electricity and heat generated by fuel (natural gas in this case) is obtained from those factories and from SimaPro.7 software databases (Table-2). The EDIP2003 method is used to assess the environmental impacts.

Global warming: In this case, the result obtained for wet process is 850 Eq kg CO_2 and 651 Eq kg CO_2 for dry process (Table-3). Table-4 summarizes all the elements which have contributed to each impact category. It demonstrates that for the dry process, CO_2 contributes at 12.8 % and CO at 87.1 % but for wet process CO_2 contributes at nearly 100 %.

It was noticed that for every ton of C_3S (alite) produced from $CaCO_3$, 579 kg of CO_2 gas is liberated as chemical by-product, irrespective of the process used and its fuel efficiency [1]. The relevant gas emissions related to the greenhouse effect in LCA analyzed are CO_2 which are more than 99 % of total global warming for those processes (wet and dry process), while other climatically relevant gases such as nitrous oxide and methane are emitting in very small quantities in clinker production [7].

Acidification: In this case, 6.12 m^2 obtained for wet process and 568 m^2 of terrestrial surface for dry process with difference about 98.9 % have nearly the same results obtained by Josa *et al*. [8] and Cesar *et al*. [9] in European cement manufacturing plants.

The main emission of SO_2 and NO_X in the production of cement occurs during the high energy combustion at high temperature of fossil fuel used to produce clinker and those

TABLE-2
LIFE CYCLE INVENTORY

Raw material and energy	Dry process (Sour El Ghozlane cement manufactory)	Wet process (Rais Hamidou cement manufactory)
Iron (Ton/Ton cement)	0.016	0.037
Sand (Ton/Ton cement)	0.044	0.65
Limestone (Ton/cement)	1.069	1.254
Clay (Ton/Ton cement)	0.078	0.044
Gypsium (Ton/Ton cement)	0.062	0.059
Tuff (Ton/Ton cement)	0.150	0.150
Water (m^3/Ton cement)	0.259	0. 924
Electricity (KWh/Ton cement)	103.362	121.038
Gas (m^3/T cement)	75.897	212.906
Gas-oil (L/Ton cement)	1.071	1.735
Oil (L/Ton cement)	0.122	0.217
Fat (L/Ton cement)	0.101	0.053
CO (kg/Ton cement)	1.540	0.192
CO_2 (kg/Ton cement)	797.00	850
NO_X (kg/Ton cement)	0.430	0.712
Particulate (kg/Ton cement)	0.155	0.089

TABLE-3
IMPACTS ASSESSMENT AND COMPARATIVE STUDY

Parameters	Wet process	Dry process
Global warming (Eq kg CO_2)	850	651
Ozone formation (vegetation) (m ^{2} ppm h)	10.6	1.56×10^4
Ozone formation (human) (Persan ppm h)	0.00085	1.26
Acidification (m^2)	6.12	568
Aquatic eutrophization EP (N) (kg N)	0.0684	6.34
Human toxicity of air (m^3)	9.12×10^3	1.35×10^7
Human toxicity of water (m^3)	0.00528	0.49
Human toxicity of soil (m^3)	2.08	194

TABLE-4
ELEMENT CONTRIBUTION TO IMPACT CATEGORIES

Impacts	Element contribution	Unit	Dry process	Wet process
Global warming	Carbon dioxide	Eq kg CO_2	83.3	850
Global warming	Carbon monoxide	Eq kg CO_2	567	0.384
Ozone formation vegetation	Carbon dioxide	m^2 ppm h	1.56×10^{-4}	10.6
Ozone formation human	Carbon dioxide	person ppm h	1.26	0.00085
Acidification	Nitrogen dioxide	m^2	568	6.12
Eutrophization aquatic	Nitrogen dioxide	kgN	6.34	0.0684
Human toxicity (air)	Carbon monoxide	m^3	1.35×10^7	9.12×10^3
Human toxicity (water)	Nitrogen dioxide	m^3	0.49	0.00528
Human toxicity (soil)	Nitrogen dioxide	m^3	194	2.08

used by mechanical equipment and vehicular transport, but can also come from raw materials used in the production of clinker and the fraction of SO_2 which is not chemically combined that is emitted into the atmosphere. These emissions caused by the production of clinker, which has general effects such as, acidification and eutrophization [10].

Human toxicity water: In this case, 0.49 m^3 is obtained for dry process, which is greater than obtained for 0.00528 m^3. This impact is due to nitrogen dioxide in both of them. In other impact categories such as: air and soil toxicity, the dry process is superior as compared to wet. Those impacts are due to formation of nitrogen dioxide (100 %).

Aquatic eutrophication: In this case, dry process generates approximately 6.34 kg N, which has more impact than wet process 0.0684 kg N with difference of 98.9 %. This is due to the quantity of NO_2 emitted in each case (6.34 kg for dry and 0.0684 kg for wet process).

It is estimated that 57.2 and 13 % of acid emission is due to fuel production and direct emission from kiln and final cement production which is related to the emission of fluorine and its inorganic compounds bauxite (54 %), barium (34 %) and other mainly heavy metals (3 %) [11].

Toxicity of air and soil: In this study, we estimated that dry process generate more impact toxicity for human beings by soil or air, than the wet process. It is caused by particulate and use of water which contributes the increase in the amount of generated particles.

Schumachar *et al*. [12] conducted a study on 80,976 inhabitants living in area next to the cement manufactory. The results showed that there is an increase of 37 %, which is due to emission from the plant, especially due to the emissions of metals such as Cr and Cd. The increment lifetime cancer risk for the population living in the vicinity of the plant would be of 0.2 % for total population of the area and this risk would be of 0.03 % for those living in the village. Those emissions have relation with meteorology and different operating conditions [12].

Conclusion

From this study, it is concluded that dry process has more impact than the wet process, because it consumes more raw materials and generates more particulate and gas in air. Those impacts can be reduced by using raw materials, which generate less pollution and replace energy by other sources of heat, which have fewer emissions. It also shows that all the generated impacts are due to atmospheric emissions.

REFERENCES

1. E. Gartner, *Cement Concr. Res.*, **34**, 1489 (2004).
2. M.B. Ali, R. Saidur and M.S. Hossain, *Renew. Sustain. Energy Rev.*, **15**, 2251 (2011).
3. J.H. Delong and R.C. Aitken, Factorial Analysis of Cement Kiln, Portland Cement Company of Utah 84104 USA (1981).
4. N.J. Sell and F.A. Fischbach, *Resour. Recov. Conserv.*, **2**, 119 (1976).
5. Environmental Road Mapping Initiative (ERI), Cement Impacts, Risks and Regulations; http://ecm.ncms.org/ERI/new/IRRcement.htm%23profile [accessed 10.10.04].
6. T. Engin and V. Ari, *Energy Convers. Manage.*, **46**, 551 (2005).
7. N.A. Madlool, R. Saidur, M.S. Hossain and N.A. Rahim, *Renew. Sustain. Energy Rev*., **15**, 2042 (2011).
8. C. Valderrama, R. Granados, J.L. Cortina, C.M. Gasol, M. Guillem and A. Josa, *J. Cleaner Prod*., **25**, 60 (2012).
9. A. Hasanbeigi, C. Menke and L. Price, *J. Clean. Prod.*, **18**, 1509 (2010).
10. D.N. Huntzinger and T.D. Eatmon, *J. Clean. Prod.*, **17**, 668 (2009).
11. R.G. Hunt, W.E. Franklin and R.G. Hunt, *Int. J. LCA*, **1**, 4 (1996).
12. M. Schumachar, J.L. Domingo and J. Garret, *Environ. Res*., **95**, 198 (2004).