Environmental impact assessment of a nitrogenous fertilizer (CAN 27% N) production in the Algerian plant

Ali MAKHLOUF[*1, 3] Gaetana QUARANTA[2], Ramdane KARDACHE[1], Raouf CHAABIA[1]

[1] *Mouloud MAMMERI University, Department of Geological Sciences, Tizi-Ouzou, Algeria*
[2] *Institut Pluridisciplinaire Hubert Curien, UMR 7178-CNRS/Strasbourg, France*
[3] *Food Technology Research Laboratory, M'hamed Bougarra University of Boumerdes, Algeria*

*Corresponding author:
Fax: +213-26-100-516
Email: almakhsme@gmail.com

Abstract

This paper aims to assess the environmental impact of a fertilizers produced in Algeria. The Functional Unit chosen for this study is One ton of CAN at 27% of Nitrogen.

In first, a detailed inventory of energy and materials flows for all life cycle of the product has been completed, and primary data collection was executed at the production facilities located in Algeria and completed by "Ecoinvent" database.

Particularly, the energy performance and Greenhouse Gases (GHG) of the product (CAN 27% of N) were assessed. Evaluation of the impact was carried using GEMIS 4.7 software according to life Cycle Assessment (LCA) method and expressed with the "CML" method.
Results have focused on the assessment of energy efficiency (Cumulative Energy Requirement (CER)) and of GHG emissions quantification. Global Warming Potential (GWP) is very significant due to the GHG emission of 2.46 t CO_2 eq/FU of CAN. CO_2 is the most important GHG emission factor with 1.21 T/T of CAN. The results show that the Algerian fertilizers production process is characterized by its high energy requirement (13.49 GJ/T of CAN), this request higher than the world average.

The overconsumption in the Algerian process increases the cumulative energy requirement. Two factors contribute to explain this overconsumption of energy in the Algerian fertilizers production process, the first is related to the multiple restarts of the plant following the failures that usually occur. The second factor is the efficiency of the catalytic reaction in the upstream processes (NH_3 and HNO_3).

1. INTRODUCTION

Fertilizer industry requires large amounts of resources and has a number of negative environmental effects; studies have estimated that fertilizer production currently accounts for about 2-3% of global energy consumption (European Commission, 2007), and is responsible for about 1.2% of the global greenhouse gas (GHG) emissions (G. Kongshaug, 1998). In 2015, the global demand on N fertilizers nutrients has reached $110.03x10^6$ tons, and will reach $118.8x10^6$ by 2020 (FAO, 2017).
Production processes are continually optimized, and this is to meet the economic requirements of a global market in continuous expansion. However, environmental issues have not received much importance for a long time.
This study is a cradle-to-Gate study assessment of a N fertilizer called Calcium Ammonium Nitrate (CAN) at 27% N. The goal is to identify and measure the consequential impacts on the environment, and to provide those concerned with useful information to analyze and identify

all those life cycle phases that have significant impacts.

2. METHODOLOGY

2.1.Description of the Cement Plant

The Fertial-annaba complex (originally called ASMIDAL) was commissioned in 1972 to meet the needs of the domestic market for fertilizers. Its primary mission is the development, production and marketing of nitrogenous and phosphoric fertilizers and chemicals such as ammonia and nitric acid.

As a result of the partnership signed on August 2005 with the Villar-Mir Group, the company invested 200 million dollars in the restoration of equipment (FERTIAL-News, 2012). This gave "Fertial-Annaba" a good place on the national market, since it guarantees the economic independence of the country in this strategic sector.

2.2. Life Cycle Assessment

LCA is a method for products and services environmental performance assessment (Heijungs et al., 2013). This technique is considered as a decision-making tool, characterized by its ability to take into account the incoming (raw materials and energy) and the outflows (emissions to air, water and solid waste) flows for the system, and to report all this data to a functional unit according to the objectives of the study (ISO 2006a, 2006b).

2.2.1. Goal and Scope, Functional Unit and System Boundaries

Nitrogen (N) provided by NAC is essential for the growth and good development of most plants. It constitutes the most limiting major element for the growth of these plants. It is an essential constituent of proteins, nucleic acids and chlorophyll. It is therefore both a factor of growth and quality (UNIFA, 2013). The functional unit chosen for this study is the production of one (1) ton of CAN 27% N.

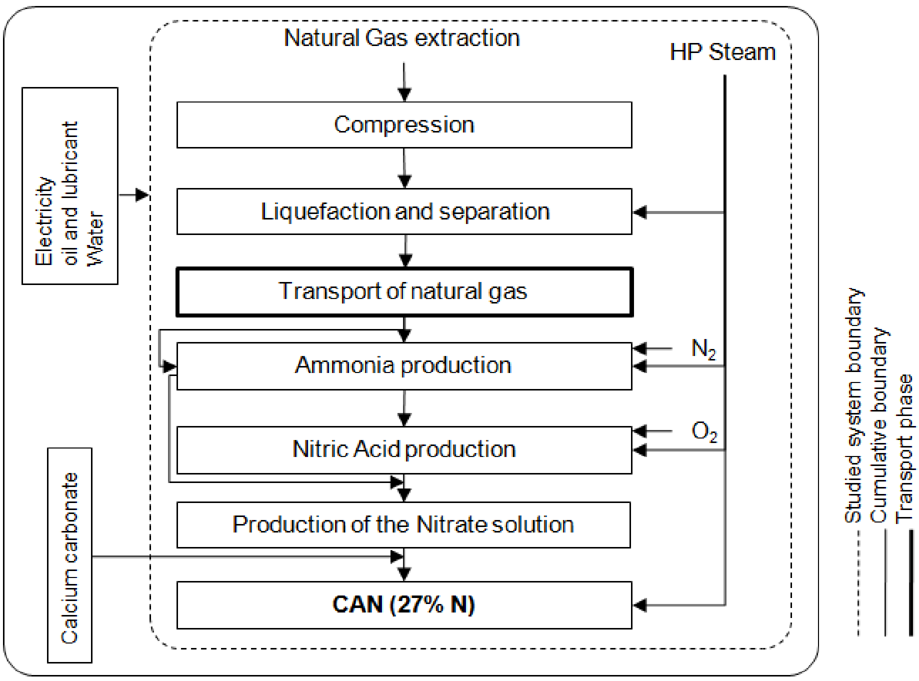

Fig.1. System Boundaries for CAN 27% N Production

The goal of this study is to determine the environmental performances of a fertilizers production plant by conducting a “cradle-to-gate” LCA study. To reach this objective, a study of the various process operations is necessary, to determine the role and particularities of each stage. The main operations that make up the CAN 27%N fertilizer life cycle of are summarized in fig.1.

2.1.2. Life Cycle Inventory and Data Quality

Fertilizers production phase is entirely carried out at the "Fertial-Annaba" industrial complex. Consumption data relating to the annual production of the plant are presented in table 1.

Table 1. Annual inventory of plant consumption

Inputs	Unit	Annual Consumption
Natural gas	Nm^3	**366 039.7x10^3**
Electricity	GJ	**45 097.92**
Water	m^3	**341 868.98**
HP Steam	T	**311 745**
Ammonium sulfate		**7 239**
Ammonium nitrate		**53 844.71**
Calcium carbonate		**4 745.43**
Grinded phosphorus		**15 402.5**
Phosphoric acid		**12 107**

3. RESULTS

3.1. Life Cycle Impact Assessment

The purpose of this study is to assess energy consumption and global warming of the studied system, and to know how much the fuel type and or processing technologies used impact the overall global warming potential of Portland cement production.

The results obtained in the LCI phase was used for assessing the environmental impact of the studied product, those impacts was carried out according to "CML" life cycle impact assessment method and using a life cycle assessment software called “GEMIS 4.7”.

Global Emission Model for Integrated Systems (GEMIS) 4.7 is a life cycle analysis database program developed as a tool for the comparative assessment of environmental effects of energy by Öko-Institut and Gesamthochschule Kassel (GhK) (IINAS, 2011; Makhlouf et al., 2015; Serradj, et al., 2016).

3.2. Global warming mid-point impact

The one ton production of CAN (27% N) contributes to global warming by generating GHGs by 2.46 t CO_2 eq. The main greenhouse gases are CO_2, N_2O and CH_4 by 46.2%, 49.18% and 4.62% respectively.

CO_2 is generated mainly in the ammonia plant; its emission is due to the combustion of “fuel gas” during the reforming of “process gas” by 70.35%, the second source is “electricity generation” by 22.84%, compressors used in gas transport by 3.42%, steam production in both production sites by 3.01%.

Natural gas extraction and processing are responsible for 97.82% of CH_4 emitted to the atmosphere; the rest is due to its transport by pipeline and electricity generation by 1.31% and 0.6% respectively.

The generation of N_2O is mainly due to the production of nitric acid by 99.77%.

3.3. Cumulative Energy Consumption (CEC)

Cumulative Energy Consumption (CEC) is 13.49 GJ / T CAN, this quantity is mainly used to supply energy to the system (electricity generation, steam production), non-renewable energies (gas, oil and coal) have 99.99% of CEC, the consumed amount of natural gas is 13.46 GJ. The consumption of coal and oil does not exceed 3.06 MJ and 26.8 MJ respectively.

3.4. Comparison of results

Table 2 shows GHG emission results for previous studies. Wood and Cowie (2004) determined a European average of 1.82 T CO_2eq/T CAN. Kool et al, (2012) have determined a global average of 2.61 T CO_2 eq/t, they explain this, by taking into account additional emissions for the production and transportation of fossil fuels.

In the figures below, the results of all the atmospheric emissions assigned to the corresponding phases of life are presented.

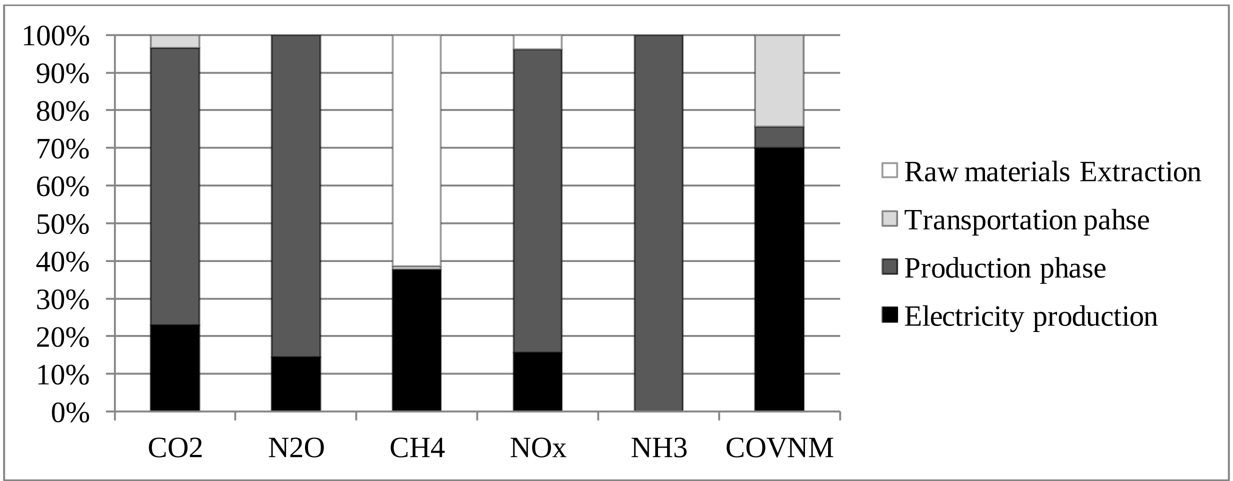

Fig.2. The contribution of the main emission factors in the life cycle phases

Table 2. GHG emission results for the production of one ton of CAN

Region	Value	Unite t/t	Reference
Suede	2,336	CO_2 eq/ t CAN	Wood et Cowie. (2004)
European Average	1,82		
Europe: Modern technology	0,8		
Netherlands	1,9		
European Average	2,567		Kool et al. (2012)
Western Europe	2,208		
Russia and Central Europe	2,565		
China and India	3,261		
Rest of the world	2,249		

4. Conclusion

The Algerian process is based on the exclusive use of natural gas as fuel and raw material for ammonia (ammonia is the basic feedstock for N fertilizers). This particularity is an advantage for the Algerian process because besides the fact that the European industry is more developed than the Algerian, we notice that the GHG emission from the Algerian process is remarkably lower than those of the other studies. This difference may be related to upstream processes (processing and transportation of natural gas). The natural gas used in the Algerian process is extracted from Hassi R'mel in southern Algeria. The production and transportation of 1 GJ of natural gas cause an emission of 3.612×10^{-3} t CO_2 eq (result the current study).

European plants based on natural gas use a gas mix transported from Russia, Norway and Algeria, whose share of Russian gas is the more important with 34% (Kool et al., 2012). The length and complexity of the gas treatment process affect the amount of GHG emission (8.957×10^{-3} t CO_2 eq/GJ of natural gas) (IINAS, 2011).

Despite its low energy efficiency, the Algerian process seems to be favored by the use of natural gas as an exclusive source of energy. The high LHI of natural gas, and its low CO_2 emission factor, makes the Algerian process a low CO_2 emitter. Upgrading the plant and continuous maintenance, are two factors that further reduce the carbon footprint in the Algerian process.

References

European Commission. IPPC, Integrated Pollution Prevention and Control (IPPC). Reference document on Best Available Techniques (BAT) for the Manufacture of Large Volume Inorganic Chemicals - Ammonia, Acids and Fertilizers. 2007. p 418. On line at: http://eippcb.jrc.ec.europa.eu/reference/BREF/lvic_aaf.pdf

FAO, Food and Agriculture Organization of the United Nations (FAO). 2017. World fertilizer trends and outlook to 2020. On line at : http://www.fao.org/3/a-i6895e.pdf

FERTIAL, 2012. La fertilisation des céréales et la sécurité alimentaire, Fertial news, N° 25, On line at : http://www.fertial-dz.com/pdf/fertial_news_n 25.pdf

Heijungs R, Guinée J.B, Huppes, G, Lankreijer R.M, Udo de Haes H.A, Wegener Sleeswijk A, Ansems A.M.M, Eggels P.G,Van Duin R. de Goede H.P. Environmental Life Cycle Assessment of products. Guide-October 1992. NOH report 9266 Leiden: Centre of Environmental Science, Pp 96. ISBN: 90-5191-064-9.

IINAS, I. I. for S. A. and S. (2011). GEMIS, Global Emission Model for Integrated Systems. IISAS, International Institute for Sustainability Analysis and Strategy. Retrieved from http://iinas.org/gemis-de.html

International Standard Organization (ISO) 14040. Environmental management—life cycle assessment: principles and framework. Geneva: International Organization for Standardization; 2006a.

International Standard Organization (ISO) 14044. Environmental management—life cycle assessment: requirements and guidelines. Geneva: International Organization for Standardization; 2006b.

Kongshaug G. *Energy consumption and greenhouse gas emissions in fertilizer production*. Proceedings on IFA Technical Conference, Marrakech, Morocco, 28 September-1 October; 1998. Pp 1–14.

Kool A, Marinussen M, Blonk H. LCI data for the calculation tool Feed print for greenhouse gas emissions of feed production and utilization. GHG Emissions of N, P and K fertilizer production. Gravin Beatrixstraat 34, 2805 PJ Gouda, Netherlands: Blonk Consultants; 2012.

Makhlouf, A., Serradj, T., & Cheniti, H. (2015). Life cycle impact assessment of ammonia production in Algeria: A comparison with previous studies. *Environmental Impact Assessment Review*, *50*. **DOI**: https://doi.org/10.1016/j.eiar.2014.08.003

Tayeb Serradj; Ali Makhlouf; Monia Serradj Ali Ahmed, Application of life cycle assessment to the case studies of new nitrogen fertiliser production, *International Journal of Global Warming*, 2016 Vol.10 No.1/2/3, pp.216 – 229, **DOI**: 10.1504/IJGW.2016.077914

UNIFA, Union des industries de la fertilisation (UNIFA). De quoi se nourrit une plante ?. 2013. On line at : http://www.unifa.fr/nourrir-les-plantes/de-quoi-se-nourrit-une-plante-.html#azote

Wood S, Cowie A. *A review of greenhouse gas emission factors for fertilizer production. Cooperative Research Centre for Greenhouse Accounting*, for IEA Bioenergy Task 38. 2004.