Eco. Env. & Cons. 27 (August Suppl. Issue) : 2021; pp. (S270-S274)

ISSN 0971–765X

ZA fertilizer environmental impact based on life cycle assessment on its production

Terannisa N. Balqis[1]*, Aditya P. Iswara[2,3] and Rachmat Boedisantoso[1]

[1]Department of Environmental Engineering, Faculty of Civil, Planning and Geo Engineering, Institut Teknologi Sepuluh Nopember Surabaya, Indonesia
[2]Department of Civil Engineering, College of Engineering, Chung Yuan Christian University, Taiwan
[3]Department of Environmental Engineering, College of Engineering, Chung Yuan Christian University, Taiwan

(Received 20 October, 2020; Accepted 18 April, 2021)

ABSTRACT

ZA fertilizer is ammonium sulfate fertilizer commonly used in Indonesia to increase nitrogen and sulfur content in the soil. ZA fertilizer production consists of six stages; carbonation unit, reaction unit, filtration unit, neutralization unit, evaporation and crystallization unit, and drying and cooling unit which produce air emission, specifically carbon emission. This study was conducted to identify the environmental impact of ZA fertilizer using the Life Cycle Assessment (LCA) method based on data on raw materials, chemicals and fuels used, products and emissions resulting from its production process. Life cycle impact assessment was analyzed using midpoint approach with TRACI 2.1 method in Sima Pro 9.0. The result shows that acidification is the largest impact generated with 2.42 x 10w kg SO_2 eq, in the Neutralization unit. The acidification in this unit is caused by addition of sulfuric acid to neutralize the liquor and electricity usage which resulting ammonia and carbon dioxide emissions.

Key words : *ZA fertilizer, Environmental, Life cycle assessment*

Introduction

Indonesia is a country which produce many agriculture products to meet the demand of food consumption (Harsono, 2009). In the agriculture area, nutrient balance is important to produce good quality of harvest. Therefore, fertilization is needed for balancing soil nutrients (Mahaputra *et al*., 2016). Sulfur and nitrogen is important nutrient for soil and Indonesian farmers mostly use ZA fertilizer for fulfilling those nutrient (Arief *et al*., 2016). Since ZA fertilizer is basic nutrient need for soil and most farmer use it for their farming, the fertilizer production is rapidly increases. However, the production of the ZA fertilizer may generate emission, for example, the form of nitrogen oxides (NO, N_2O, NO_2). Other gases are scattered in the atmosphere include water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), hydrogen sulfide (H_2S) with chloro-fluoro hydrocarbons, such as halon gas. The existence of these gases may cause the greenhouse effect and global warming (Savci, 2012). Other environmental impact potentially occurred in water and soil. Therefore, environmental impact assessment based on ZA fertilizer production is important for identifying the impact during its production process.

We use Life Cycle Assessment (LCA) principle to determine the environmental impact. LCA is an analytical method that can be used to analyze environmental loads at all stages in the product life cycle starting from resource extraction, the production process of the materials and products themselves, and the use of the product until the product is disposed of in other words cradle to grave (Bruijn *et al*., 2002). The tool that isused to identify the environmental impact on this process is Sima Pro 9.0. Other study mentioned that the software is used as an analytical tool to measure the input and output process, environmental impact and the efficient use of resources that focus on the life cycle of a product.

Methods

Goal and Scope

Goaland scope definition is important to help consistency of the Life Cycle Assessment (LCA) analysis. The goal in this LCA research is to identify the environmental impact caused by the ZA fertilizer production process, while the scope of this LCA research includes the following:

- LCA analysis in the ZA fertilizer production process is carried out in a gate to gate which includes the all production processes. The diagram of the ZA fertilizer production process is illustrated in Figure 1.
- LCA analysis using SimaPro 9.0 tools with a midpoint approach using the TRACI 2.1 method which includes ozone depletion, global warming, smog formation, acidification, eutrophication, human health cancer, human health non cancer, human health criteria pollutants, ecotoxicity, and fossil fuel depletion.

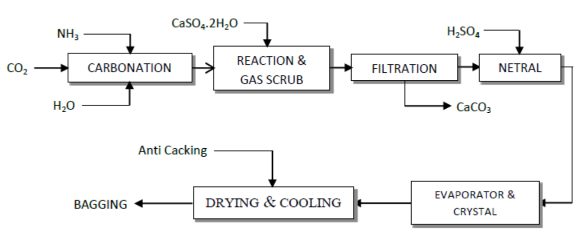

Fig. 1. Process flow diagram of ZA fertilizer plant.

Life Cycle Inventory

LCA analysis is carried out based on data inventory on the production process which includes raw materials, chemicals and fuel used, and emissions resulting from the production process of ZA fertilizer. Data inventory is collected from petrochemicals industry such as the amount of raw materials and chemicals used, the use of electricity and fuel, material balance data, the number of products, and emission load data generated in each unit of the ZA fertilizer production process. These data acquired from design data on ZA fertilizer plant. After inventory data stage, environmental impact of the ZA fertilizer production process was carried out using TRACI 2.1.

At this stage, quantitative data collection measures the input and output of a product system. In determining the Life Cycle Inventory analysis requires input data which includes analysis of raw materials, chemicals and fuels used, as well as output data in the form of products and emissions resulting from the ZA fertilizer production process. The data used for LCA analysis must be representative, that is, by meeting the minimum data collection standards for 1 year (EPA, 2016). For the example, the complete results of the input data inventory and output for Carbonation unit of ZA fertilizer production process can be seen in Table 1.

Table 1. Carbonation unit inventory.

No	Input	Quantity	Output	Quantity
1	CO_2 gas	93,169 t	NH_3	2,607 t
2	Ammonia vapor	70,821 t	CO_2	1,125 t
3	Scrubber liquor	215,461 t	H_2O	196 t
4	Condensate	186 t	Carbonated liquor	357,709 t
5	Electricity	2,542,320 kWh		

Life Cycle Impact Assessment

LCA is a stage to evaluate potential impacts on the environment by using the results of the life cycle inventory and providing information to interpret the final phase (Hermawan *et al*., 2013). In this study, a midpoint impact assessment approach was used. This is because the midpoint approach is more specific and emphasizes the psycho-chemical changes in the environment. The method used in this LCA study is the TRACI 2.1 method which is analyzed using SimaPro 9.0 software. Impact categories is analyzed using the TRACI method include ozone depletion, global warming, smog formation, acidification, eutrophication, human health cancer, human health non cancer, human health criteria pollutants, ecotoxicity, and fossil fuel depletion (Menoufi *et al*., 2011).

The stages in the life cycle impact assessment (LCIA) consist of characterization, normalization, weighting, and a single score. However, in this study only an assessment was carried out at the characterization and normalization stages to focus on the goal of this study. The impact assessment aims to identify how much a process contributes to the environmental impacts resulting from that process.

1. The characterization stage

The characterization stage is the stage of identifying and classifying input data from LCI into predetermined impact categories according to the method and database used. This stage will measure the impact contribution of a product or activity to each impact indicator. The value of the environmental impact at the characterization stage was obtained from calculations using SimaPro 9.0 software.

2. The normalization stage

The normalization stage is a procedure required to show the relative contribution of all impact categories to all environmental problems and is intended to be a unitary general for all impact categories. The normalization value can be determined by multiplying the characterization value with the normalization factor, thus the impact value from the impact assessment results for each process unit can be compared.

Life Cycle Interpretation

The interpretation stage (Life Cycle Interpretation) is the last step in the LCA. The interpretation of the results consists of two steps, namely identification of important issues and evaluation. At the stage of identifying important issues, interpretation of the results is carried out to see consistency in the inventory of inputs, outputs, and environmental impact assessments. At this stage, a part of the process will be determined where efforts to reduce emissions need to be done. The data used in this study consisted of observations, direct interview data with factory employees, company documents and data from relevant previous studies (ISO, 2006).

Results and Discussion

Environmental Impact on ZA Fertilizer

Based on the characterization result, it can be identified that a particular process unit is the largest contributor to an impact category. Global warming is indicated as largest environmental impact with 4.88 x 10x kg CO_2 eq contributed mostly from Evaporation unit with 2.8 x 10x kg CO_2 eq. Ozone depletion generate 9.88 kg CFC-11 eq which contributed mainly from Evaporation averagely around 2.73 kg CFC-11 eq. Smog formation with a total impact value of 4.39 x 10v kg O_3 eq, the Evaporation unit was the biggest contributor to the impact, namely 2.22 x 10v kg O_3 eq. In the impact of acidification with a total impact value of 2.42 x 10w kg SO_2 eq, the Neutralization unit was the biggest contributor to the impact, namely 1.29 x 10w kg SO_2 eq. In the impact of eutrophication with a total impact value of 1.55 x 10v kg N eq, the Neutralization unit was the biggest contributor to the impact, which was 8.12 x 10u kg N eq. On the impact of ecotoxicity with a total impact value of 1.08 x 10x CTUe, the Reaction unit was the biggest impact contributor, which was 3.58 x 10w CTUe. In the impact of fossil fuel depletion with a total impact value of 1.14 x 10y MJ of surplus, the Evaporation unit was the biggest contributor to the impact, namely 5.97 x 10 x MJ of surplus. In the carcinogenic impact with a total impact value of 1.47 CTUh, the Reaction unit as the largest impact contributor is 0.435 CTUh. For non-carcinogenic impacts with a total impact value of 4.16 CTUh, the Reaction unit was the largest impact contributor, namely 1.33 CTUh. In the respiratory effect with a total impact value of 8.75 x 10u kg $PM_{2.5}$ eq, the Neutralization unit was the largest contributor to the impact, namely 4.56 x 10u kg $PM_{2.5}$ eq. The detail results of characterization stage calculation scan be seen in Figure 2.

After calculating at the characterization stage, it is then necessary to calculate the environmental impact at the normalization stage.Normalization stage can identify the biggest impact contributors to each process unit from different impacts. It can be seen that Carbonation unit generate acidification as the largest contributor with number of 32,400. In the Reaction unit, the impact of carcinogenic was the largest contributor to the impact, amounting to 18,700. The detailed results of the impact assessment on normalization stage calculations can be seen in Figure 3.

Potential Hotspot of ZA Fertilizer Production

From the entire process unit, it can be seen that the process unit that produces the largest impact value is the Neutralization unit with a total impact magni-

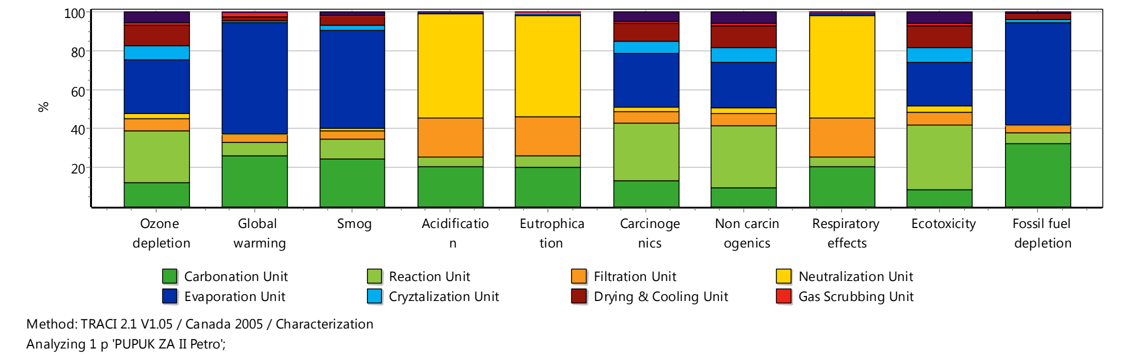

Fig. 2. Graph of characterization value on ZA fertilizer production process.

tude of 1.51 x 10u. The sequence of the results of calculating the environmental impact value in each process unit sorted from the highest impact value to lowest impact value can be seen in Table 2.

Table 2. Impact contributor from different production unit.

Process unit	Impact value
Neutralization Unit	1.51 x 10u
Carbonation Unit	8.08 x 10t
Filtration Unit	6.35 x 10t
Evaporation Unit	4.76 x 10t
Reaction Unit	4.14 x 10t
Drying & Cooling Unit	9.51 x 10
Crystallization Unit	6.14 x 10
Dryer-Cooler Scrubbing Unit	4.81 x 10
Gas Scrubbing Unit	1.39 x 10

From the calculation of the environmental impact value on the entire ZA fertilizer production process, it can also be identifiedthe largest impact category (impact hotspot). Determining the hotspot point is very important to do in order to minimize the greatest impact that is generated, so that it is more targeted. The impact hotspot is the acidification impact with the value of 1.56 x 10u which is caused by the large number of uses of chemicals during the entire production process that has the potential to produce acidic waste and emissions. The order of environmental impact categories sorted from the highest impact value to lowest impact value can be seen in Table 3.

From the entire process unit, based on the data in Table 2, it is stated that the process unit that produces the largest impact value is the Neutralization unit with a total impact is 1.51 x 10u. In order to obtain a more accurate analysis result, it is necessary to study deeper the cause of highest impact in Neutralization unit. It is found that in the Neutralization, neutralized liquor and electricity dominantly contribute to the environmental impact as shown in Table 4.

Table 3. Environmental impact category classification with same unit.

Impact category	Impact value
Acidification	1.56 x 10u
Eutrophication	1.14 x 10u
Carcinogenic	6.32 x 10t
Global warming	2.08 x 10t
Fossil fuel depletion	2.04 x 10t
Respiratory effects	1.19 x 10t
Ecotoxicity	1.03 x 10t
Non carcinogenics	4.63 x 10
Ozone depletion	2.47 x 10
Smog formation	2.15 x 10

Based on Table 4 above, it can be seen that the category of acidification impact is the biggest impact resulting from the production process in the Neutralization unit, which is a total of 8.31 x 10t. Acidification is the process of increasing the concen-

Table 4. Impact value on Neutralization unit.

Impact category	Total	Neutralized liquor	Electricity
Ozone depletion	68.7	0	68.7
Global warming	96	38.1	58
Smog formation	20.6	0	20.6
Acidification	8.31 x 10t	8.31 x 10t	24.1
Eutrophication	5.97 x 10t	5.95 x 10t	111
Carcinogenics	1.53 x 10	0	1.53 x 10
Non carcinogenics	137	0	137
Respiratory effects	6.21 x 10	6.2 x 10	7.98
Ecotoxicity	310	0	310
Fossil fuel depletion	104	0	104
Total	1.51 x 10u	1.48 x 10u	2.37 x 10

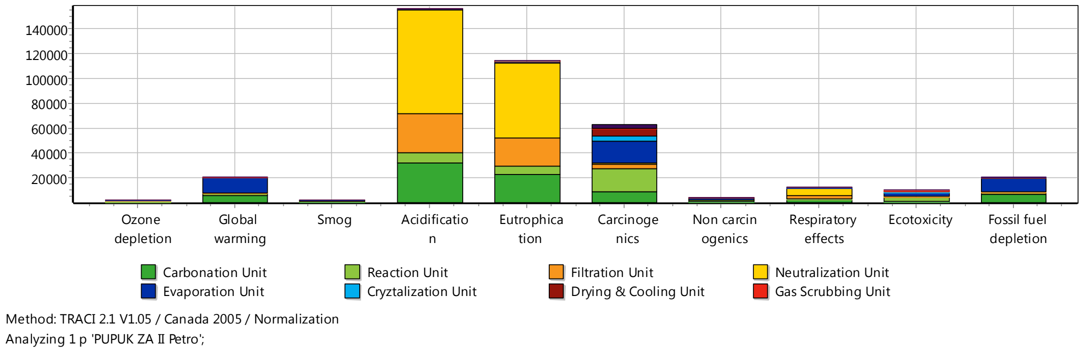

Fig. 3. Graph of normalization value on ZA fertilizer production process

tration of hydrogen ions (H^+) in the environment, where acid gas reacts with water in the atmosphere to form acid rain. Gases that cause acid deposition such as ammonia (NH_3), nitrogen oxides (NO_x) and sulfur oxides (SO_x).

In the carbonation unit, it can be seen that there are still unreacted NH_3 and CO_2 which enter the reaction and filtration unit. To neutralize the excess NH_3, sulfuric acid is needed so that it increases the concentration of the Ammonium Sulfate (ZA) solution which is carried out in the neutralization unit with operating conditions at a temperature of 55-75 °C with a pH of 3-4. With so many acidic materials used in this process, it can cause potential waste, both liquid waste and acidic emissions that can cause pollution. Based on the LCIA results,it is found that in the Neutralization unit, the main cause of acidification is the content of ammonia compounds and other acidic compounds found in neutralized liquor products and emissions in the form of ammonia gas produced.

Conclusion

Based on the results of the Life Cycle Assessment (LCA) analysis, the three impact categories that have the greatest impact value of the entire ZA fertilizer production process are the acidification impact (1.56 x 10u), eutrophication (1.14 x 10u), and the carcinogenic (6.32×10^4), respectively. The impact hotspot is the acidification impact with a characterization value of 2.42 x 10w kg SO_2 eq and a normalization value of 1.56 x 10u, while the process hotspot or process unit that produces the largest impact value is the Neutralizationunit.

References

Arief, Adiba, Septania Yolan K.L., Khalil Mubarak, Imelda Pong Labba, and Baso Agung. 2016. The Use of ZA Fertilizer as Inorganic Pesticides to Increase the Yield and Quality of Tomato and Big Chilli (in Indonesian Language). *Journal of FIK UINAM*. 4(3).

Bruijn, Hans De, Robbert van Duin and Mark A.J. Huijbregts. 2002. *Handbook on Life Cycle Assessment.* Kluwer Academic Publisher: New York.

Environmental Protection Agency (EPA). 2016. Guidance on Data Quality Assessment for Life Cycle Inventory Data. United States.

Harsono, Dwi. 2009. Agricultural Development in Favor of the Farmers (in Indonesian Language). *Journal of Information* (in Indonesian Language), No. 2, XXXV.

Hermawan, F., Puti, F.M., Muhammad, A. and Driejana, R. 2013. The Role of Life Cycle Analysis (LCA) on Construction Materials in an Effort to Reduce the Impact of Carbon Dioxide Emissions on Greenhouse Gases (in Indonesian Language). *National Conference of Civil Engineering of Sebelas Maret University.*

International Standard Organization (ISO). 2006. ISO 14040 Enviromental Management – Life Cycle Asessment – Principles and Framework. Switzerland (CH): ISO.

Mahaputra, A. Hendy, Ni Gst, Ag. Gde, Eka Martiningsih, and Cokorda Javandira, 2016. The effect of ZA fertilizer on the growth and yield of mustard plants (*Branssisca juncea* L.)" (in Indonesian Language). *Journal of Ecosystem Balance Based Agriculture (in Indonesian Language).* Denpasar: Mahasaraswati University.

Menoufi, K.A.I., Casol, A.C. and Cabeza, L.F. 2011. Life Cycle Analysis and Life Cycle Impact Assessment Methodologies: A State of The Art. Lleida: Universitat de Lleida.

Savci, Serpil. 2012. An Agricultural Pollutant: Chemical Fertilizer. *International Journal of Environmental Science and Development*. 3 (1).