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Environmental Impact Assessment of Brick Production in Indonesia

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***Abstract*—Brick is one of the building materials commonly used in building construction materials. The production activities of the brick industry have a lot of potential that can cause problems in the environment such as water, soil and air pollution. The purpose of this study is to analyze the potential environmental impacts in the form of emissions and waste from brick production activities by applying the LCA method to the brick production process and to identify the inputs and outputs of the brick production process. To gain a deep understanding, a small enterprise of brick manufacturer was selected as a case study. The results of this study indicate that electricity and cement are the biggest causes of each category of impact. The category of potential global warming impact is the largest with a total of 6.95 kg CO2-eq. Although in all categories the percentages are more or less the same. This happens because the brick production process which almost entirely uses electrical energy in the production process and also the use of cement in large quantities has a major impact on the environmental impact.**

***Index Terms*—impact assessment, environment, brick production**

I. Introduction

Brick is one of the building materials commonly used in building construction materials. Brick is composed of a mixture of coarse sand, Portland cement and water which is printed solidly or press [1]. The general shape of the brick is a rectangle with a standard size of 20-30 cm long, 8-10 cm thick and 14-18 cm high. In general, people use brick as a component of walls in buildings because it has several advantages over other building materials such as red brick. The advantages of bricks are that they are larger than red bricks, so they require less bricks and adhesive materials such as cement when carrying out construction, their waterproof nature minimizes leakage and is also lighter. However, bricks also have disadvantages, one of them is easy to crack.

There are several factors that can affect the compressive strength of the bricks, namely the water-cement factor, the age of the bricks, the density of the bricks and the balance of the materials used in the production process of the bricks. The comparison between the weight of water and the weight of the cement used is very important in the process of mixing materials, while for the compressive strength of the brick, the longer the age of the brick, the higher the compressive strength of the brick. In the mixing process, it is attempted to make the density as dense as possible. This is so that the materials bind to each other so that the strength level of the bricks can increase.

Coal, which is generally used as an energy source, turns out to produce and leave residues from the combustion process. The resulting residue is in the form of material that is released into the air and settles to the bottom. The combustion products are considered as waste and can pollute the environment, therefore the use of residues from the coal combustion process is reused as a cement substitute mixing material in the production process of bricks. Before being used as a substitute for cement in the production of bricks, the residue from burning coal is tested first. Tests were carried out to see the level of density of the bricks and the compressive strength of the bricks. As is known in general, brick is a construction material, especially in the manufacture of walls, which has a low price and relatively strong because it is made of a mixture of sand, cement and water.

In Indonesia, the brick industry is quite common, one of which is the SME located in Yogyakarta. The production activity of the brick industry has a lot of potential that can cause problems in the environment such as water, soil and air pollution. In order to overcome the problems that occur as a result of the brick production activities, the application of the life cycle assessment (LCA) method can be used to identify emissions and waste generated from the production activities of the brick industry. LCA is a method for analyzing and calculating the total environmental impact of the product life cycle [2]. LCA can be used to determine the potential for waste to be generated, the raw materials needed and also how much energy consumption is used [3]. LCA consists of four stages, namely the determination of objectives and scope, inventory analysis, impact assessment, as well as interpretation and analysis of improvements. [4]. In a previous study, Supriadi [5] stated that based on the LCA method, brick is a material that has a better impact on the environment than bricks in the process of making walls.

The scope of this LCA research is gate to gate which is the scope of the shortest life cycle analysis because it only reviews activities that are closest to discussing the process from the production stage. The scope is used to determine the environmental impact of a production step or process [6]. The purpose of this study is to analyze the potential environmental

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impacts in the form of emissions and waste from brick production activities at one of the MSMEs in Yogyakarta. The application of the LCA method is also expected to be able to identify inputs and outputs from the production process and find out critical points in the entire process.

II. Research Methodology

Research stages conducted consisting of literature study, field observations, interviews, as well as data collection and processing. As shown in Fig.1, environmental impact analysis of the brick production process is carried out using the LCA method, which consists of four stages, namely determination of objectives and scope, inventory analysis or life cycle inventory (LCI), environmental impact analysis or life cycle impact assessment (LCIA), and interpretation [6]. LCA results can be applied to product development, strategic planning, public policy making, and marketing.

Determination of objectives and scope is the first stage in conducting an LCA analysis. This stage was made with the aim of determining the limits and scope of analyzing LCA [2]. In this study, the limitation of the system used is gate-to-gate which includes only the production process. This process starts from the distribution of the main ingredients for making bricks such as sand, water and cement, then the process of mixing the materials, molding the bricks, to marketing the finished bricks.

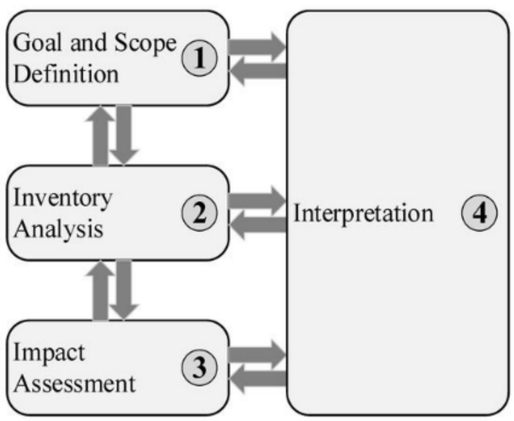

Fig. 1. The LCA Framework

Furthermore, inventory analysis is carried out by collecting data and calculating the flow of raw materials and energy needed in the brick production process, as well as the output (waste and emission). From the results of inventory analysis, it will be obtained the amount or amount of the need for raw materials, energy and emissions generated from the production process. After performing LCI, LCA modelling was performed using GaBi software. From the software, the LCIA was carried out by selecting the CML 2001 method for the environmental impact category. This method is an impact assessment that limits quantitative modeling to an early stage in the cause-and-effect chain to limit uncertainty. Results are grouped into midpoint categories according to a common mechanism. In this study, only four impact categories were selected, namely global warming potential (GWP), ozone depletion potential (ODP), abiotic depletion elements (ADE), and human toxicity potential (HTP). The results of the LCIA were analyzed and identified critical points for each category of environmental impact. Then, the last stage is the interpretation of the results and the design of improvement strategies.

III. Results And Discussion

Brick is the main material in a building. One of the uses of this material as a component for making walls. The functional unit determined in this study was brick with a weight of 1 kg. As presented in Figure 2 and Table 1, Brick production begins with the process of mixing sand, cement and water. The raw materials are stirred using a mixer machine. After that, the next process is the molding of bricks using an automatic brick press machine that uses a vibrating system. The advantage of using a vibrating brick machine is that it has more production capacity and is very easy to maintain. After the bricks are printed, the next process is to dry the bricks and arrange them neatly in the storage area. The output of this production process produces 1 kg of bricks and 0.05 kg of solid waste.

TABLE I.
LCI Result

Input				
Flow	**Quantities**	**Amount**	**Units**	**Origin**
Cement (Minerals)	Mass	1	kg	Estimated
Electricity (Electric Power)	Energy	10.1	kwh	Calculated
Ground Water (Water)	Mass	2.5	kg	Estimated
Limestone Sand 0-3.5 mm (Limestone)	Mass	1	kg	Estimated
Output				
Flow	**Quantities**	**Amount**	**Units**	**Origin**
Concrete Brick	Mass	1	kg	Calculated
Other Waste (Production Residues in Life Cycle)	Mass	0.05	kg	Estimated

From the data that has been collected in the LCI process, then the LCA model is designed using the help of GaBi software. As shown in Fig.2, this model describes in detail the inputs and outputs arising from the brick production process. Furthermore, the potential environmental impacts were analysed using the 2001 CML method. There were four categories of impacts selected, namely GWP, ODP, ADE, and HTP. These four impact categories were selected according to the scope of the research (gate-to-gate).

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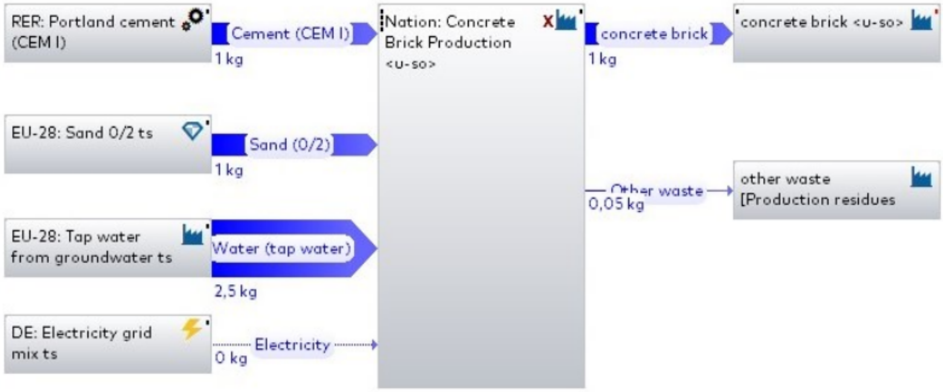


Fig. 2. LCA Modelling Using GaBi Software

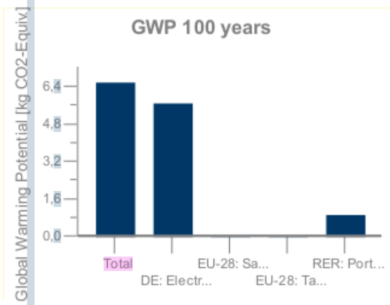
The biggest causes for each category of impact are the consumption of electrical energy and cement. Cement is an important binder in the construction industry and is produced in large quantities worldwide. The cement production process requires a lot of heat energy. About 40% of the total cost of the cement industry is used for fossil fuels, such as coal, where this fuel is usually used as a source of energy in the cement industry [7]. High cement production will cause environmental pollution, because the intensive use of natural resources will affect the work of residents around industrial areas [8]. The most important impact of the high energy consumption of the cement industry on the environment is exhaust emissions, especially exhaust emissions. Carbon dioxide emissions that affect climate change [9]. It is estimated that the cement industry accounts for 57% of global carbon dioxide emissions. The high emissions of the cement industry are driven by high global cement production and demand, and cement is expected to continue to grow [10].

As shown in Fig. 3, there are four categories of environmental impacts derived from the LCIA results. The first category is GWP. This category focuses on the environmental impact of global warming. The brick production process in this study has an impact on GWP in 100 years. The most contributing impact is the use of electrical energy and cement with a total of 6.95 kg CO_2-eq., in electrical energy of 5.68 kg CO_2-eq. and cement of 0.901 kg CO_2 eq. The second category is ODP. This category focuses on the environmental impact of the potential reduction or depletion of ozone caused by chemical compounds. The results of the LCIA diagram on the brick production process in this study show that the most contributing impact is cement with a total of 4.4e-8 kg R11-eq. Next, the third category is ADP. This category focuses on the environmental impact of the potential depletion of non-fossil natural resources. The results of the LCIA diagram on the brick production process show that electrical energy contributes the most by producing 2.35e-6 kg Sb-eq., then cement produces 1.46e-6 kg Sb-eq. The last category is HTP. This category focuses on the environmental impact of the potential environmental impact, which is pollution from the air that has a negative impact on human health. The results of the LCIA diagram on the brick production process in this study show that electrical energy produces 0.2 kg DCB-eq. while cement is 0.0925 kg DCB-eq. The total amount of the two is 0.293 kg DCB-eq. Based on the LCA results, the recommendation for improvement is to apply the concept of sustainable manufacturing to the brick production process. To reduce the environmental impact, the brick production process must conserve energy and use natural resources efficiently.

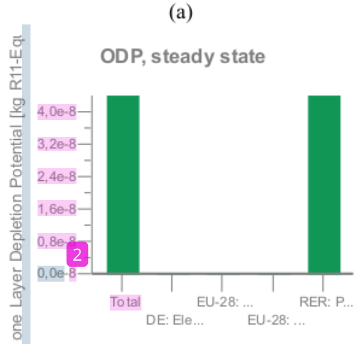
One of the applicable concepts to support the sustainable manufacturing is the cleaner production. Cleaner production is an environmental management strategy used in production chain with the aim of increasing efficiency in the use of raw materials, energy and water, minimizing waste and emissions resulting from the production process, thus it is more environmentally friendly and cost effective [11]. According to the Ministry of Environment [12], before implementing the concept of cleaner production, industries must first understand prevention strategies related to waste reduction. Some of the strategies include re-think, reuse, recovery, reduction and recycle. Among them, the key strategies are re-think and reduction because of the importance of thinking about the implications of brick production and how to minimize the use of raw materials to reduce environmental impacts. If the re-think and reduction strategies still cause pollution or waste, only then do the next 3R strategy (reuse, recycle, and recovery) as a strategy for waste management levels.

Commonly, the production process of bricks uses raw materials that are dominantly derived from nature such as cement, water and sand. The density of the bricks also affects the strength of the bricks themselves, therefore the composition of the bricks must be balanced. The use of water in the composition of the brick is useful so that the mixing process between cement and other compositions can be combined [13]. Indrasisti & Fauzi [14] described several cleaner production applications in an industry that can be applied to the following elements:

1. Production process: implementation of cleaner production includes increasing efficiency and effectiveness in the use of raw materials, energy and resources as well as reducing the use of materials that can damage the environment thereby reducing potential waste and emissions.
2. Products: the focus of cleaner production is to reduce the impact of the entire product life cycle from raw materials to product disuse.
3. Services: cleaner production seeks to apply the use of 3R processes for every activity in the production chain.



(a)



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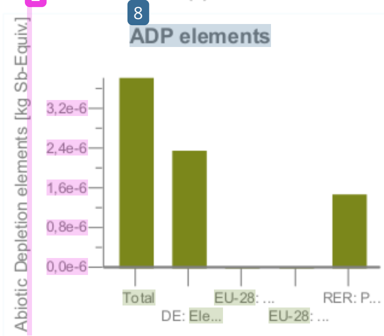

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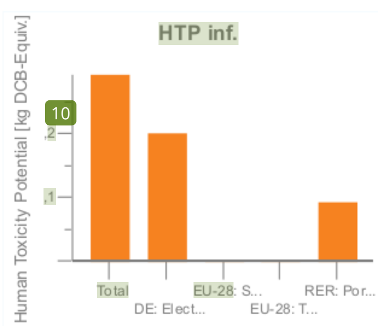

(d)

Fig. 3. LCIA Diagram of (a) GWP, (b) ODP, (c) ADP, and (d) HTP

IV. Conclusion

From the research that has been done on the production process of bricks using the LCA method, the results of the analysis of potential environmental impacts for the four categories, namely GWP, ODP, ADP, and HTP have been obtained. For example in the impact category, GWP, the use of electrical energy and cement are the processes that have the biggest impact..This happens because the production process of bricks almost entirely uses electrical energy in the production process and the use of cement in large quantities has a major impact on the environment.

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