LIFE CYCLE ASSESSMENT OF SILICON FROM BAGASSE ASHES

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ABSTRACT: *Ashes of bagasse comes from the combustion of the bagasse used for steam boilers in sugar mills. Ashes of bagasse content valuable compound components that can be processed into silicon. Utilization of bagasse ashes into silicon can reduce the impact on the environment in addition to providing added value of bagasse ashes. The purpose of this study is to values analyze and environmental potential impacts as well as the potential impact sources of the silicon production process plan from the bagasse ash. The method used is a life cycle assessment of a 1 kg / hour silicone production process in the factory (cradle to gate) with a capacity plan of 10,000 tons / year. Analysis results of silicon life cycle assessment of bagasse ash using software simapro 8.1.16 PhD with single issue method of IPCC 2013 GWP 100a versi 1.01 gives the value contribution of CO_2 emissions total for 103 kg CO_2 equivalent/ hour, and North American TRACI.2.1.VI.03/Canada 2005 method that shows such the total effect to respiratory disorders for 1.62 kg PM2.5 equivalent/ hour, total carcinogenic cause is 8.8E-6 CTUh/hr, Total Eco-toxicity is 1.21E3 CUTe/hour and the smog is 7.96 kg O_3 equivalent/hour. Based on the results of life cycle assessment analysis, it is vitally required efforts to reduce the potential value and impacts that arise.*

KEYWORDS: Bagasse Ashes, Silicon, Life Cycle Assessment

INTRODUCTION

Sugar is one of the basic needs of households in Indonesia, while the raw material for sugar is sugarcane. Therefore in 2014, the Government has launched a sugar self-sufficient program in an effort to meet the increasing demand for sugar annually. If the population of Indonesia in 2014 were 253,000,000 then increased to 255,000,000 in 2015, the condition will impact on the increase of sugar from 11.24 kg per capita to 11.32 kg per capita (Indonesian Sugar Association, 2013).

The potential of bagasse in Indonesia, according to Indonesian Sugar Plantation Research Center (P3GI, 2008), is quite large with the average composition of sugar industry byproducts in Indonesia consists of 52.9% liquid waste, 3.5% *blotong* (waste), 32.0% sugarcane drops 4.5% and 7.05% sugar and also 0.1% bagasse with volume of 232,294 tons per year whic can be used as pulp for paper mill, cattle fodder, fertilizer raw material, particle board, bioethanol and other utilizations. It is estimated that 60% bagasse has been utilized and the remaining 40% has not been utilized (P3GI, 2008). The dried bagasse is generally used for combustion energy resource of steam boilers in sugar mills itself. The result of combustion in the form of bagasse

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ash has a silica dioxide compound of 70.97%, this is according to the analysis result from affiliation and consulting industry team at ITS Surabaya.

The silica dioxide contained in the bagasse ash is estimated to have an impact on the environment which can effect on both humans and plants. For the impact on human health is the decrease on lung function or better known as Pneumoconiosis which is one of the main diseases caused by work (Fardiaz 1992, Sucipto, 2007 and Susanto, 2011) And its effect on plants is that if the ash combines with water vapor or drizzle water, it forms a thick crust on the surface that cannot be washed with rainwater except by rubbing it, the layer of crust covers the leaf mouth that blocks photosynthesis process and prevents CO_2 exchange with atmosphere. That is due to the particle size is 1-10 microns (Fardiaz 1992 and Hesaki 2004). Data from World Health Organization (WHO) in 1999 showed that there are 1.1 million deaths from occupational diseases worldwide, 5% of which are from Pneumoconiosis. In routinely surveys conducted in the UK on surveillance of work-related and occupational respiratory disease (SWORD), it showed Pneumoconiosis almost always ranked 3-4 each year.

Additionally, untreated bagasse ash in sugar mills contributes to emissions (Purwaningsih, 2016). The three major greenhouse gases consisting of CO_2, CH_4, and N_2O are generated from burning fossil fuels, sugar production process activities, agricultural activities, and waste handling and treatment (Wei et al 2008). The effect of the presence of greenhouse gases that has now been felt is the increase in temperature on earth. This increase in temperature causes further effects such as melting of polar ice, rising sea levels, disrupting agriculture and indirectly ultimately impacting a country's economy (Darwin 2004).

Some efforts is needed to reduce the impact. One of the ways is to use the ashes of bagasse into silicon. This utilization will increase the added value of bagasse, create new business opportunities and become an alternative way to reduce the silicon use originated from of non-renewable natural resources, and also reduce the import of silicon. Utilization of bagasse ashes into silicon is expected to be input for the government in building the eco-industry. As the definition of sustainable development is how to organize development that meets the needs of mankind, without diminishing the ability of future generations to meet their needs (WCED, 1987).

METHODOLOGY

The data of this research are sourced from silicon import number (BPS, 2014) and mass balance analysis of the silicon industry plan from bagasse ash. The calculation of mass balance is used to conduct analysis of silicone life cycle assessment (LCA) from bagasse ash. A set of computers with software simapro 8.1.16 PhD (single issue IPCC 2013 GWP 100a version 1.01 and TRACI.2.1.VI.03 / Canada 2005) and Microsoft Office are used to assist the analysis process.

The life cycle assessment is a method for evaluating the input, output and potential environmental impacts of the product system throughout its life cycle (ISO 14044: 2006), this is divided into four stages, namely (1) the purpose and scope (2) inventory analysis (3) impact assessment (4) interpretation result (ISO 14044: 2017).

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RESULT AND DISCUSSION

Purpose and Scope

The purpose of this research is to conduct assessment analysis and potential impact of silicon from bagasse ash, on maximum capacity plan 10.000 ton/year with scope of life cycle assesment *cradle to gate* (process inside the factory). Calculation analysis is using functional unit 1kg/hour silicone product, with production system carried out continuously for 24 hours. This research does not include transportation calculation system of raw material procurement, building construction process and equipment manufacture. The determination of production capacity of silicon from bagasse ash is based on domestic needs which are still imported and the world's silicon demand whish is expected will continue to grow.

Inventory

At this stage of invetarization, it starts from the production capacity determination of silicon from bagasse ash that is 10.000 ton/year, followed by making the flowchart of silicon production from bagasse ash. Every process in production flowchart has (input) bagasse, hydrochloric acid, magnesium and water, solar (diesel fuel) for its input energy, electricity from the state electricity company (PLN) for utilization and natural gas for the process of purification of each input after being processed that will produce emission as the output.

Mass balance is initially made to know the input and output process. The value on the mass balance will become the basis of determination of the functional unit (fu) on the process of making silicon from bagasse ash, with the functional determination of the unit is 1 kg. The flowchart process of input and output of the silicon production process from bagasse ash is as follows:

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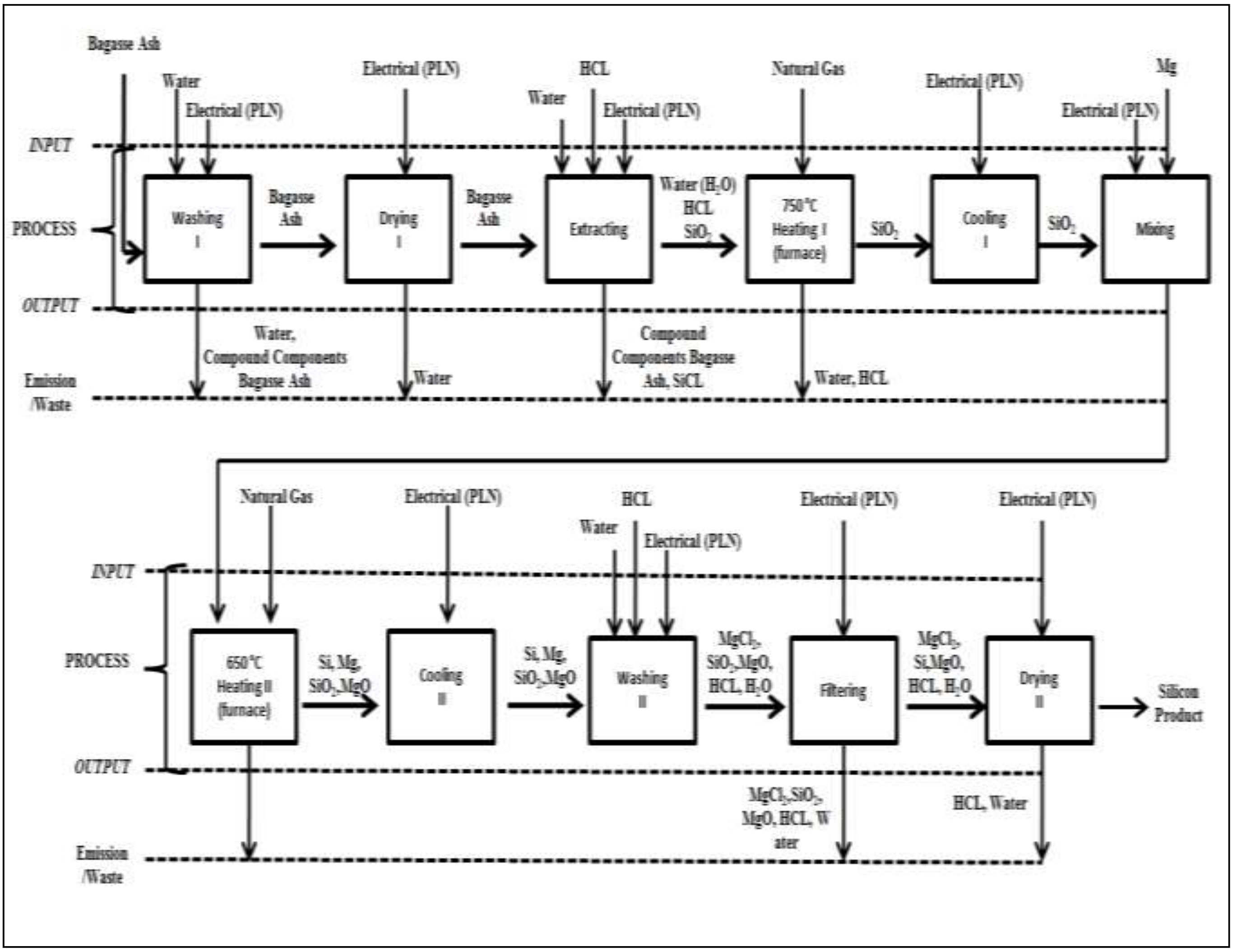

Figure 1. Flowchart and silicon production limits of input & output of silicon from bagasse ash

Impact assessment

The impact assessment is to estimate the environmental impact of all inputs and outputs accumulated in the inventory. The impact assessment is used to analyze the impact of a process to the environment and human health that has been quantitatively recorded on inventory handling. In the classification, inventory data associated with potential effects on ecology and human health are placed in several categories.

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Table 1. Values and impact sources of 1 kg/hour silicon production from bagasse ash using single issue IPCC 2013 GWP 100a version 1.01

No	Impact source	Unit (Kg CO_2 equivalent)
1	Electricity from PLN	7.74E-5
2	Magnesium (Mg) of the filtration process	0.00673
3	Silica dioxide (SiO_2) from the dissolution process	0.00841
4	Hot steam	0.00917
5	Magnesium oxide (MgO) of filtration	0.198
6	Water (H2O) from filtration	0.269
7	Acid chloride (HCl) from filtration	0.362
8	Magnesium dichloride ($MgCl_2$) of filtration	0.834
9	Silicon (Si) from filtration	9.42
10	Compound components of bagasse ashes which are not products	91.7
	Total	103

Table 2. Values and impact categories of silicone production 1 kg / hour from bagasse ash using North American TRACI.2.1.VI.03 / Canada 2005 method.

No	Impact categories	Unit
1	Acidification	5.58 SO_2 equivalent
2	Effects of respiratory disorder	1.62 kg PM2.5 equivalent
3	Carcinogenic	8.8E-6 CTUh
4	Eco-toxity	1.21E3 CTUe
5	Smog	7.96 kg O_3 equivalent

Interpretation

By using software analysis simulro 8.1.16 PhD method of single issue IPCC 2013 GWP 100a version 1.01 as in table 1, to produce 1 kg / hour of silicon production from bagasse ash, contributes total emission of CO_2 of 103 kg CO_2 equivalent per hour. The impact source comes from the heating process that uses natural gas energy and electricity usage from the State Electricity Company (PLN), in addition to the source of the impact, the biggest impact source comes from the process of filtration of the components of bagasse ash which does not become a silicon product. Required bagasse ashes is 50,795,08 ton/year, become silicone product 10.000 ton / year and not become product 40,795,08 ton / year. Bagasse ashes have components

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of $C_5H_8O_4$ (22, 27%), MgO (0.82%), Na_2O (0.43%), K_2O (4.82%), Fe_2O_3 (0.36%), Al_2O_3 (0, 33%) and SiO_2 (70.97%). The compound component which does not become the product is silica dioxide (SiO_2) 70.97% and the remaining components of the other compounds that do not become products.

If the impacts sources on Table 1 that have not been treated and then released into the air, and the SO_2 and NOx compounds resulted react with water vapor (the acidification process), this will oxidize and produce sulfuric acid and nitric acid in the clouds and fall to the ground in the form of rain or snow / wet deposition (Mason 1993). The compound components of bagasse ash which do not become the products or waste materials contain carbon that is $C_5H_8O_4$. Waste materials requiring oxygen contain carbon as the most element. One reaction that occurs with the help of bacteria is the oxidation of carbon to carbon dioxide, the reaction as $C + O_2 \rightarrow CO_2$. In this reaction required 32 grams of oxygen to oxidize 12 grams of carbon, so carbon requires oxygen three times its weight to carry out the reaction. Such reactions are called perfect combustion reactions, but prior to CO_2 formation there may be temporary oxidation products such as ammonia, hydrogen sulfide, methane. Besides having bad smell the compounds are also toxic to animals, plants and humans (Fardiaz 1992). In addition, the impact sources in Table 1 can result a decrease in the oxygen content in the water, due to excess nutrients that affect the decrease of oxygen in the water body (eutrophication). If the dissolved oxygen concentration is too low, the active anaerobic microorganisms produce $C \rightarrow CH_4$, $N \rightarrow NH_3$ + amin, $S \rightarrow H_2S$, $P \rightarrow PH_3$ + fosfor component.

The method used in table 2 is more varied, there are 5 categories of impact compared with table 1 which has 1 category of impact that is global warming only. In table 2 that is still using software simapro 8.1.16 PhD with North America method TRACI.2.1.VI.03 / Canada 2005, there are 5 categories of impacts such as the acidification process of 5.58 SO_2 equivalent, total respiratory disorder effect 1.62 kg PM2.5 equivalent, total carcinogenic causes 8.8E-6 CTUh, total Eco-toxity of 1.21E3 CTUe and smog of 7 , 96 Kg O_3 equivalent.

The value and impact source, other than derived from the components of the bagasse ash which is not a product, may also be derived from the use of chemical compounds such as hydrochloric acid (HCL) for the separation of organic compounds other than silica, separated organic compounds and hydrochloric acid does not become a product which possibly contribute to value and impact to the environment as shown in tables 2 and 3. As for magnesium (Mg) is used for the process of forming silica dioxide into silicon. The same as hydrochloric acid, magnesium compounds do not become products or into byproducts. If there is processing effort, this will also contribute to the environment as in tables 2 and 3.

Efforts made to reduce the value and the impact, by technology approach is making waste water treatment plant (WWTP) for waste water treatment generated and the use for dust catcher. The environmental management approach can be by utilizing byproducts to become a substitute for both silicone production and other production and tree planting. Process management is also done by replacing heating energy from natural gas to bagasse. With this approach, it is expected that the value and impact that may be generated can be reduced.

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CONCLUSION

The analysis results of the life cycle assessment (LCA) of the industry plan of silicon from bagasse ash for 1kg / hour gives value contribution and environmental impacts, such as to global warming, human health problems and environmental degradation. The source of the impact comes from the production process, the use of chemical compounds, the use of fossil fuels, and untreated or unprocessed byproducts. Thus it is necessary to reduce the value and environmental impacts so that sustainable development can be achieved.

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