Environmental Impact Evaluations for Treatment Technologies of Palm Oil Mill Effluent Using LCA and Multi-Criteria Decision Support System

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Abstract

Palm oil mill effluent (POME) is the liquid waste from palm oil mills, and it is generally treated using open lagoon technology. Open lagoon technology for POME treatment should be combined or replaced by another alternatives technology since open lagoon technology known not environmentally friendly. On the other hand, Indonesia sustainable palm oil (ISPO) has a regulation that POME treatment by open lagoon technology have to change to other alternative technology by 2020. The objective of this study was to find the best alternative technologies for POME treatment considering benefit, opportunity, risk, and cost. Also determine the more environmental friendly alternatives POME treatment technology as the preferred POME treatment technology in North Sumatera, Indonesia. This study was applying life cycle assessment (LCA) for those alternative technologies and selection that alternative using multi criteria decision analysis (MCDA). AHP and ANP Calculation and analysis was follow Saatys' theory and was performed on questionnaire data using Expert Choice® and Super Decision Software®. LCA calculation and analysis based on LCA standard assessment by following the ISO 14040 series. SimaPro® version 8.1.1.16 was used as the LCA analysis tool. The alternatives POME treatment technologies were the combinations of open lagoon technology (COLT) with composting (COLT-Composting), COLT-Biogas, COLT-Electrocoagulation and COLT-Microalgae. COLT-Biogas technology consists of three major types: composting, land application, and membrane technology. Related to the AHP study with the selected criteria were benefit, opportunity, risk, and cost, and sub-criteria further determined based on these criteria. The sub-criteria were revenue, greenhouse gas (GHG) reduction, employment absorption, corporate social responsibility (CSR), co-processing, environmental risk, marketing risk, technology reliability, investment cost, operation and maintenance cost, and opportunity cost. The alternatives were COLT-Composting for fertilizer purpose, and COLT-Biogas for energy generation purpose, both of technology has been on the commercial level of technology. COLT-Composting proved to be the superior COLT using tentative performance of alternative in this research, with advantages in benefit, opportunity, and risk. The priority weight for COLT-Composting was 63.6%. Sensitivity analysis was performed by changing criteria priorities. For COLT-

Biogas to be considered better than COLT-Composting, the cost would need to be weighted more than 95.4%. In order to estimate the environmental impacts of these technologies, the LCA system boundary was from gate to gate, and unit per ton of fresh fruit bunch as a functional unit. The environmental impact is evaluated by focusing on global warming potential (GWP), acidification potential (AP), eutrophication potential (EP), human toxicity potential (HTP), energy consumption (EC), and net energy ratio (NER). The results presented herein indicate that the GWP was the most important term in the POME environmental impact assessment. As the LCA result, with respect to GWP, COLT-Biogas integrated with composting was more environmentally friendly than the other combinations. Approximately 357.18 kg CO2-eq of GWP reduction could be achieved with this technology without considering the utilization potential of its products. In terms of EC, COLT Biogas with membrane technology required the lowest amount of energy among the alternative technologies. Concerning NER, COLT-Biogas with land application and membrane technology achieved better results since they do not require fossil fuel input. This study proposed the new method that uses a sequence of LCA and MCDA method for evaluate and compare the POME alternatives treatment technology. The sequence method was use LCA as the first method and following the AHP and ANP method. Related to sequence LCA and MCDA method for POME treatment assessment, the results of GWP, AP, EP and HTP was used as criteria in AHP and ANP method. COLT biogas integrated with composting was the highest decreasing of global warming potential (96.2%) and omit the effect of eutrophication potential and human toxicity potential. For AHP results of environmental impacts as the criteria, COLT-Biogas integrated with composting as the best for POME treatment with the priority weight 43.8%. To confirm the AHP result, ANP result shows that there were no significant differences result of among the alternatives POME treatment. A novel approach of comparing POME treatment technologies is presented herein, and the findings could help decision makers and planners to adopt the more environmentally friendly policies, resulting in more sustainable palm oil products. This summary could help the palm oil mill decision makers for choosing the more environmentally friendly POME treatment technology.