APPLICATION OF INDUSTRIAL ECOLOGY SYSTEM BY APPLYING LIFE CYCLE ANALYSIS: A CASE STUDY IN A PALM OIL MILL

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ABSTRACT

Palm oil industry plays an important role in the economic development of Malaysia and in enhancing the economic welfare of the population. Despite the obvious benefits, this industry also significantly contributes to environmental degradation, both at the input and the output sides of its activities. On the input side, crude palm oil mills use large quantities of water and energy in the production processes. On the output side, manufacturing processes generate large quantities of wastewater, solid waste/by-products and air pollution. This case study was conducted to introduce industrial ecology system to use palm oil mill wastes and byproducts in a sustainable manner while Life Cycle Analysis (LCA) approaches was used as a tool which can evaluate impact of a product from cradle to grave in palm oil mill industry. Related industries which can use palm oil wastes and by products were incorporated in the industrial ecology system approach. The energy generating system from fiber and shell was studied to investigate environmental impacts. An inventory analysis using life cycle was applied to investigate all the resources used and emissions released due to the system of energy generation. The concept of the industrial ecosystem points at the potential of industrial waste recycling resembling within the industry or with other related industries. Proposed industrial ecosystem for the crude palm oil mill industry, based on utilization of solid and liquid waste and appropriate energy management, can achieve the goal of almost zero discharge of pollutants. LCA inventory analysis showed there were no adverse impacts towards the environment, when fiber and shell used as fuel to generate energy for palm oil mill industry. Such an approach can contribute in transforming the palm oil mill into a more environmentally friendly industrial activity.

INTRODUCTION

Malaysian palm oil industry continues to contribute significantly to the country's economic development and foreign exchange earnings. Export earnings of palm oil products was recorded at RM 30.41 billion in 2004 in spite of having strong competition from other palm oil producing countries (MPOB 2005). Despite its obvious benefits palm oil mill industry contributes to environmental degradation from both input and output sides of its activities (Chavalparit et al. 2006). Environmental impacts from the palm oil industry in Malaysia can be identified from three distinct perspectives. Waste audits identify flow rates and compositions of materials that could be the targets to environmental impacts. Life cycle analysis (LCA) examines individual products, determining rates of waste generation, energy consumption and raw material usage. Industrial ecology examines the uses and wastes associated with particular materials. In this study concepts of LCA and industrial ecology were applied to identify environmental impacts in palm oil industry.

MATERIALS AND METHODS

General

The LCA was applied to find the environmental impacts when fiber and shell were used as fuels for the boiler. The "cradle" of the assessment is thus the start of the biomass fuel intake to the boiler whereas the "grave" is the generation of electricity. Amount of electricity (KWh) needed to process 45 tons of Fresh Fruit Bunch (FFB) per hour (mill capacity) was selected as the appropriate functional unit (FU) for this study.

Collection of data

Primary data consisting of fuel (fiber and shell) consumption rate (ton/hr) and amount of generated electricity (KWh) were obtained from Jugra Palm Oil Mill in Banting Selangor. Secondary data were obtained from researches undertaken at Jugra palm oil mill (Faizal 2001; Jamil 2004), various institutions in Malaysia and from literature review. Jugra Palm Oil Mill purchase FFB from other oil palm plantations for processing, as they do not have their own plantation. This mill is operated 24 hours except during shutdown for maintenance and repair. Its FFB processing capacity is 45 tons per hour.

The resource consumption and air emission (SO_2, NO_2 and particulates) data were obtained from the energy generation system in this mill. Steam pressure (bars) and volume of steam (ton/hr) generated from the boiler and the electricity generated (KWh) from the generator were recoded. Daily production data (product and waste) and earnings of Jugra Palm Oil Mill for the month of June 2006 were gathered. Primary data were used to clarify secondary data.

RESULTS AND DISCUSSION

Analysis of environmental impact

Records of the NO_2, SO_2 and particulates emission from the boiler in Jugra palm oil mill for four years (1998, 1999, 2000 and 2001) were compared with limits imposed by Department of Environment Malaysia (DOE). Table 1 shows the level of particulates, SO_2 and NO_2 emissions were within the maximum allowable limit imposed by the DOE.

Table 1 Emission to air from boiler (for 45tons/hr FFB milling capacity)

Parameter	Unit	DOE Standards (Average)	Quantity	Source	Duration Yea r(from – to)
Particulate	g/Nm^3	0.4	0.2990	Recorded data	1998 -2001
SO_2	g/Nm^3	0.2	0.0545	Recorded data	1998 -2001
NO_2	g/Nm^3	2.0	0.8476	Recorded data	1998 -2001

Source: Faizal 2001

Biomass energy for self-sufficiency

Table 2 shows energy production and utilization in Jugra Palm Oil Mill.

Table 2 Energy production and utilization in Jugra Palm oil Mill

	Fuel Generated from the system	Fuel Need	Energy produced	Energy requirement
Fiber	5.37 ton/hr	4.52 ton/hr	750/ KWh	750/KWh
Shell	3.14 ton/hr	1.12 ton/hr		

Energy produced (750 KWh) from shell and fiber are only used to operate palm oil processing machineries in Jugra palm oil mill. This amount of energy is sufficient to process 45 tones of FFB per hour (FU). Any excess amount of fiber and shell are sold. Resources balance of the energy (electricity) generating system shows that wastes generated from the system can fulfill energy requirement of the system (Table 2).

Solid waste generation

Table 3 shows computation of products for 45 ton/hr of FFB in this Palm Oil Mill.

Table 3 Wastes generated in Jugra Palm Oil Mill in June 2006

Waste	% from Fresh Fruit Bunch	for 1 ton of FFB	for 45 ton/hr
Empty Fruit Bunch	23%		10.35 ton/hr
Fiber	12%		5.4 ton/hr
Shell	7%		3.15 ton/hr
POME	50%		22.5 ton/hr
Decanter cake		42Kg	1.89 ton/hr
Ash		48Kg	2.16 ton/hr

In June 2006 Jugra Palm Oil Mill was operated for 24 hours per day basis and totally 32246.88 tons of FFB were used in capacity of 44.79 ton/hr (~ 45ton/hr).

Existing technology and improvement options

Based on the analysis of the existing material and energy flows at the Jugra palm oil mill, a model of an almost zero waste (industrial ecosystem for crude palm oil industry can be early achieved except for Palm Oil Mill Effluent (POME).

Most of Palm Oil Mill industries use these fiber and shell as fuel. In this Mill, special machinery is used to make fiber from Empty Fruit Bunch (EFB). This EFB fiber is used for the boiler, which is used for fertilizer making plant. Decanter cake (4.2%) and ash (4.8%) are used to make composed fertilizer in fertilizer making plant.

There are possibilities to use EFB to make MDF and paper pulp. EFB is a readily available waste from the oil palm industry can be used as an alternative raw material to make Medium Density Fiberboard (MDF) (Rushdan 2003). Steam generate from boilers and energy generate from POME can be used to produce either MDF/paper pulp or both. Any excess amount of energy from EFB can be used for above-mentioned system.

There is a possibility to produce activated carbon by using shell and steam (Chavalparit et al. 2006). Thus the excess amount of shell produced in Jugra palm oil mill can be used to produce activated carbon. However according to Chavalparit et al. (2006) steam and energy are needed to produce activated carbon. This mill has a system to generate energy and steam by using EFB, which is currently being used for the fertilizer plant. Therefore there is a good opportunity to use this steam for activated carbon production.

POME is the main type of waste from oil palm milling industry and Methane (CH_4) is evolved from open ponding systems used in POME treatment, accounting for 10% of the CH_4 inventory in Malaysia (Yeoh 2004). CH_4 can be used to generate electricity. This electricity can also be used to fulfill mill requirements and excess can be added to local grid line.

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