INDUSTRIAL ECOSYSTEMS IN THE CRUDE PALM OIL INDUSTRY IN THAILAND

Ph. D. candidate: Orathai Chavalparit
Advisor: Mol,T. Arthur
Co-advisor: Wim Rulken
: Sutha Kaohdiar

Abstract

The crude palm oil industry plays an important role in Thai economic development and in enhancing the economic welfare of the population. Despite obvious benefits of this industrial development, it contributes to environmental degradation from both input and output sides of its activities. On the input side, crude palm oil mill uses much water in production process and consumes high energy. On the output side , manufacturing process generates large quantity of wastewater, solid waste/ by-product and air pollution. The current breakdowns of industrial wastes and recoverable materials are empty fruit brunch, fiber, shell kernel and ash. It is estimated that by year 2002, a total of 1.8 million ton of solid wastes/ by- products and 2.5 million m^3 of wastewater are generated. Industrial eco-systems are the environment friendly systems for industrial waste recycling, resembling the food chains, food webs and the nutrient cycles in natural environment. The crude palm oil mill has developed a number of ecosystems for its waste recycling. This paper describes the nature of these eco-systems, divided as in-plant, upstream industry and cross-industry of crude palm oil industrial in Thailand based on environmentally balanced industrial complex.

1. Introduction

Industrial waste handling is the final and critical step for industrial pollution control. It is also an important issue to cleaner production and sustainable development. Industrial eco-systems are the environmental friendly systems for industrial waste recycling, resembling the food chains, food webs and the nutrient recycles in natural environment (liu and Shyng, 1999). Industrial eco-systems are much more environment friendly compared to other waste treatments such as incineration, solidification and landfill because:

- It transforms the harmful component of waste into usable substance.
- It slows down the depletion of primary resources in industrial production.

There are three stages in the evolution of an industrial ecosystem. Type I industrial ecosystem, are characterized by linear, one-way flows of materials and energy where the production, use, and disposal of products occurred without reuse, or recovery, of energy or material. In Type II industrial ecosystem ,some internal cycling of raw materials occurs, but there is still a need for virgin material input, and wastes continue to be generated and disposed of outside the economic system. Hypothetical Type III industrial ecosystem would be characterized by completes internal cycling of materials. A mix of TypeI and Tpye II material flows can characterize current industrial ecosystem. The Type III industrial ecosystem model, material is highly conserved, no waste material is released, and heat escapes It is keeping with the limiting goal of the “zero discharge” adopted by several major companies (Allenby and Richards,1994).

Chao (1999) reported that four type of industrial ecosystems are envisaged:

- In- plant ecosystem: In-plant reuse, off-spec recycle, waste minimization.
- Ex- plant ecosystem: Joint recycling of waste s among different plants in the same industry.
- Cross-industry ecosystem: Joint recycling of waste s among different industry, Eco-industrial park.
- Cross-border ecosystem: Joint recycling of waste s among the industrial sector and other sectors.

The current ecology of industrial systems suggests several environmentally desirable changes in industrial production and practices. These changes include improving efficiency and productivity of industrial systems, minimizing waste in the uses of raw materials, substituting abundant and environmentally benign materials for those that are less so, developing uses for waste products, and reusing manufacturing products at the end of their first life. The goal of efficient material and energy use suggests exploring ways in which the web of waste recycling and reuse found in natural systems may be limited in the industrial context (Allenby and Graedel, 1997). Industrial ecology asks whether Nature can teach industry ways to go much further both in minimizing harmful waste and in maximizing the economical use of waste and also of products at the ends of their lives as inputs to other processes and industries. and the role of industrial ecology is to find leverage, the opportunities for considerable improvement from practical effort. Industrial ecology can search for leverage wherever it may lie in the chain from extraction and primary production through "final" consumption, that is, "from cradle to rebirth." Mindful of the endless re-incarnations of materials

Food industry is one of the world's largest industrial sectors. In Thailand , it is the largest manufacturing industrial sector. While food processing is not considered to be amongst the most environmentally hazardous industries, they can course severe organic pollution if designed or operated with insufficient attention to the environment. To solve these and other environmental problems, the food industry should adopt cleaner production methods to pollution control Water used can be dramatically cut through in-house recirculation systems. Liquid and solid wastes can be reused within industry or different industry (Ramjeawon, 2000).

In 2002 there were some 65 crude palm oil industry in Thailand, producing about 0.6 million ton of crude palm oil from 3.5 million ton ($3.5x10^6 ty^{-1}$)of fresh fruit bunches. These factories are located in the southern part of Thailand and have traditionally been major consumers of water, and are also major sources of organic pollution in surface water bodies.. Palm oil production generates large amounts of process residues such as fiber ($5.0x10^5 ty^{-1}$), shell ($1.6x10^5 ty^{-1}$), and empty fruit bunches ($9.0x10^5 ty^{-1}$). A large fraction of the fiber and much of the shell are used as fuel to generate process steam and electricity in the palm processing mill itself. However, much is wasted by dumped in areas adjacent to the mill, or utilized as manure in the palm oil plantation. As of present, resources recycling and recovery are mostly concerned by industry The crude palm oil industry has developed a number of eco-systems for its waste recycling the nature of these ecosystems are reviewed and discussed in this paper.

2. Natural resource use

Water consumption

Crude palm oil mill uses much water in production process. Cannel water is the source of water supply that is treated by clarification and filtration. Alum and polymer are used as coagulant and flocculent in the clarifies. More than 60 % of water used is for cooling system in turbine generator, the rest of 40 % is for steam boiler. Steam from boiler is first applied to turbine generator for electricity, then supplied to sterilization, digestion, kernel dryer tank, hot water tank, and clarification tank and oil storage tank. Cooling water is also reuse in production process.

Use of process water

Water supply is required for the following process:

1. Boiler makes up water.
    - During power generation, steam from boiler is supplied to turbine generator.
    - During sterilization, live steam from boiler is applies to autoclave in order to facilitate the stripping of fruit.
    - During digestion, live steam from boiler is pumped to vessel to facilitate homogenization.
    - Heating purpose, live steam from boiler is supply to steam coil in oil settling tank, hot water tank, oil storage tank and kernel dryer tank in order to control temperature.
2. Cooling water for the turbine is used to generate electricity from burning fiber.
3. During extraction, hot water is used to remove oil from fiber
4. During remove large particle from oil in desander step, hot water is use to clean the surface of vibrating screen.
5. During oil recovery from sludge, as a dilution water for sludge to adjust the concentration of sludge before go to separator.
6. Miscellaneous usage such as seal water pump and factory and machine cleaning.

Water quantities used

It has been estimated that in year 2002 crude palm oil industry in Thailand consume about 1,240 million m^3 of water in production process. Table 1 shows the typical water use for five selected factories. It is clear from this table that water consumption per ton of empty fruit brunch among 5 factories is not different because they install water tube boiler and turbine generator which consume the same amount of water. However wastewater generation are varied by factories depend on the efficiency of water management within the factory.

Table 1. Water usage at selected crude palm oil mills.

Factory	FFB (ton/day)	Water input (m^3/ton FFB)			Wastewater (m^3/ton FFB)
		Total	Boiler	Cooling water	
A	359	1.2	0.40	0.86	0.56
B	387	1.0	0.47	0.53	0.51
C	530	1.1	0.54	0.56	0.58
D	1650	1.26	0.51	0.75	0.54
E	223	1.3	0.75	0.55	1.03

Table 2 shows the detailed water consumption at 3 factories which different in oil recovery technology and degree of wastewater recycle in production process.

- Factory A and B install decantor and separater for oil recovery from sludge and recycle wastewater from sterilizer in production process.
- Factory C and D install decantor for oil recovery from sludge.
- Factory E installs separator for oil recovery from sludge. Separator consume large amount of water because it is common practice to add hot water during centrifugation.

Table 2. Breakdown of water inputs of selected factories.

Process stream	Flow rate (m^3/ton FFB)		
	Factory A	Factory C	Factory E
Boiler make up water (steam)	**0.40**	**0.54**	**0.75**
• Sterilizes	0.15	0.25	0.15
• Digester	0.02	0.09	0.06
• Other	0.23	0.20	0.54
Water from cooling system in turbine is reuse in	**0.85**	**0.56**	**0.55**
• Screw press	(0.08)	-	0.08
• Vibrating screen	(0.005)	0.004	-
• Separator	0.10	-	0.44
• Factory cleaning	0.08	0.08	-
• Domestic purpose and other	0.68	0.49	0.02
Water use in production process	**0.58**	**0.62**	**1.30**
Total water consumption	**1.20**	**1.10**	**1.30**

Note: ( ) sterilize condense wastewater reuse in production process.

Energy consumption

The result from survey of 5 crude palm oil factories showed that electricity is the dominant source of energy for production process. Total energy consumption of all electric machines used in the production process is average 14.46 kWh/ton FFB. Palm oil mills in Thailand operate on cogeneration system using biomass residue as fuel in the boiler. The boiler produces high pressure and temperature steam, which expands in a backpressure steam turbine and produces enough electric power for the internal needs of the mill. The exhaust steam from the turbine goes to an accumulator which distributes the steam to various processes in the mill.The electricity used in this mill is distributed among 2 sources; turbine generator in factory and purchase from government supplier. The electricity generated in the factory is about 77.7 % of total electricity consumption. The power plant in the crude palm oil mill incorporates water tube boiler with a steaming capacity of 20 to 30 ton of steam/ hour. Fiber is used as fuel for generation of power in factory and used to supply the domestic purpose(3.3% of total electricity consumption).

Fuel demand.

Fuel used in the production process consists of 0.12 liters diesel oil/ ton FFB. Diesel oil is uses for diesel generator for start up boiler.

3. Industrial pollution

The entire crude palm oil process does not need any chemical as a processing aid. Therefore, all substances found in the products, by – products and residues are originated from the fresh fruit bunch. However, there are a number of pollution problems at the facility, such as high noise level from machine, high water consumption, generation of high organic content of wastewater, generation of large quantity of solid waste and air pollution (Table 3).

Table 3 Summaries of the emission associated with the crude palm oil production.

Process	Air emission	Wastewater	Solid waste
Loading ramp	-	Oil contaminated WW	-
Sterilization	Steam blowdown	High organic WW	-
Bunch stripping	-	-	Empty fruit bunch
Oil extraction	-	-	Fiber, shell
Oil clarification	-	High organic WW	Decanter cake
Oil purification	Vapor	High organic WW	-
Steam generation	Black smoke	-	Ash

Wastewater generation

In wet process operation, high quantities of water are utilized during the process of extraction of crude palm oil. Result from survey shows that rate of water consumption in production process for such industry is in the range of 0.5-1.0m^3 / ton FFB. About 66.7-100 % of the water used results in palm oil effluents (POME) as shown in table 4, 5 and 6. The others is lost in form of steam, mainly through sterilize exhaust. The total pollutant loads in the process wastewater for 5 factories discussed previously are show in table 4.

Table 4. Pollution load generated from production process of crude palm oil mill.

FACTORY	WATER USE IN PRODUCTION PROCESS (M^3/TON FFB)	WASTEWATER (M^3/TON FFB)	POLLUTION LOAD FROM PRODUCTION SOURCE (KG /TON FFB)				
			BOD	SS	OIL	TKN	TP
A	1.2	0.56	30.7	18.2	2.5	0.6	0.02
B	1.0	0.51	20.3	19.9	3.9	0.1	0.01
C	1.1	0.58	29.1	21.6	3.7	0.2	0.05
D	1.26	0.54	25.1	-	6.6	0.5	-
E	1.3	1.03	43.1	30.3	6.5	0.2	-

It can estimated that the pollution load of wastewater from standard palm oil mills in Thailand in 2002 are equal to 113 thousand ton/ year comparing with that of domestic sewage in term of BOD was equivalent to the amount of waste daily generated by 5 millions people. Malaysia faced with this pollution problem before. By 1975, crude palm oil had become the country's worth source of water pollution course by the organic wastes from the CPO mill was equivalent to the population generated by a population of more than 10 millions. Estimated pollution load from crude palm oil industry in Thailand:

- **Wastewater generation 2.24 million m^3/ year**
- **Oil loss in wastewater 16,240 ton/ year**
- **BOD in effluent 109,340 ton/year**
- **SS in effluent 79,875ton/ year**
- **TKN in effluent 1,120 ton/ year**

Table 5. Characteristics of wastewater from production process of factory A.

Source of wastewater	pH	BOD_5 (mg/l)	COD (mg/l)	SS (mg/l)	TS (mg/l)	O&G (mg/l)	Color (pt.Co unit)
Sterilizer	4.93	44,900	76,186	18,000	49,680	6,165	9,500
Decanter& separator	4.76	79,200	126,592	72,267	94,060	5,215	20,000
Influent*	4.83	56,050	79,360	30,933	57,650	7,250	10,000

* wastewater from production process and cleaning factory.

Table 6. Pollution loading from production process of factory A.

Source of wastewater	BOD_5 loading (kg/ton FFB)	COD loading (kg/ton FFB)	SS loading (kg/ton FFB)	TS loading (kg/ton FFB)	O&G loading (kg/ton FFB)
Sterilizer	5.33	9.05	2.14	5.90	0.73
Decanter&separator	30.88	49.35	28.17	36.67	2.04
Influent	33.03	46.79	18.24	33.99	4.28

*_wastewater from production process and cleaning factory.

The problems of environmental impact from POME usually occur in rainy season especially those mills, which is located close to community and / or do not own the oil palm plantation. At the early of 1990, severe pollution was course by the discharge of POME in to watercourse. Water from polluted rivers and streams became unsuitable consumption. Moreover, organic compound contaminated in wastewater was depleting the dissolved oxygen in the water. This was effect aquatic life such as fish, prawn etc. that provide a significant share of the diet of villagers.

Air pollution.

Particulate and smoke are generated from burner/boiler in wet process factories due to incomplete combustion of the solid residuals. Palm oil mills are generally self- sufficient in term of energy requirement due to the availability of adequate quantities of the fiber and shell materials used as solid fuel in the steam boiler.The data showed that particulate matter from boiler is about 717 mg/ m^3 (range of 593-893 mg/ m^3). In all cases, air emissions have pollutants higher than the limits mentioned in the National Quality Standards of 400 mg/ m^3.

Solid waste and by – products

Solid waste and by – products generated in the palm oil extraction process are empty fruit bunches; fibers; shell; decanter cake and ash from boiler. The quantities of these materials are summarized as shown in table 7. In 2002, Thai crude palm oil industry produce 0.6 million tonnes per year of palm oil from 3.5 million ton of fresh fruit bunches. Palm oil production generates large amounts of process residues such as fibre 0.5 million ton, shell 0.16 million ton, and empty fruit bunches 0.9 million ton. Solid waste can be reused in production process, oil palm plantation and sold to other industry.

A large fraction of the fibre and someof the shell are used as fuel to generate process steam and electricity in the palm processing mill itself. However, much is wasted by dumped in areas adjacent to the mill, or utilized as manure in the palm oil plantation. Palm oil mills in Thailand operate on cogeneration system using biomass residue as fuel in the boiler. The boiler produces high pressure and temperature steam which expands in a backpressure steam turbine and produces enough electric power for the internal needs of the mill. The exhaust steam from the turbine goes to an accumulator which distributes the steam to various processes in the mill.

Table 7. Quantity of solid waste/by-product generated for 4 selected factories.

SOURCE	SOLID WASTE GENERATED (KG / TON FFB)					
	Factory A	Factory B	Factory C	Factory D	Factory E	Mean
Empty fruit brunch	230	300	230	220	240	240
Fiber	140	150	140	140	140	140
Shell	55	40	40	60	44.5	60
Kernel	55	50	30	60	28.5	60
Decanter cake	32	50	57	30	-	42
Ash	50	77	17	-	-	48

Solid waste can be reused in production process, oil palm plantation and sold to other industry. Various palm oil solid waste handling methods. The problems of solid waste management in factory are improper storage and handling of solid waste material and improper land application techniques or practices for solids waste.

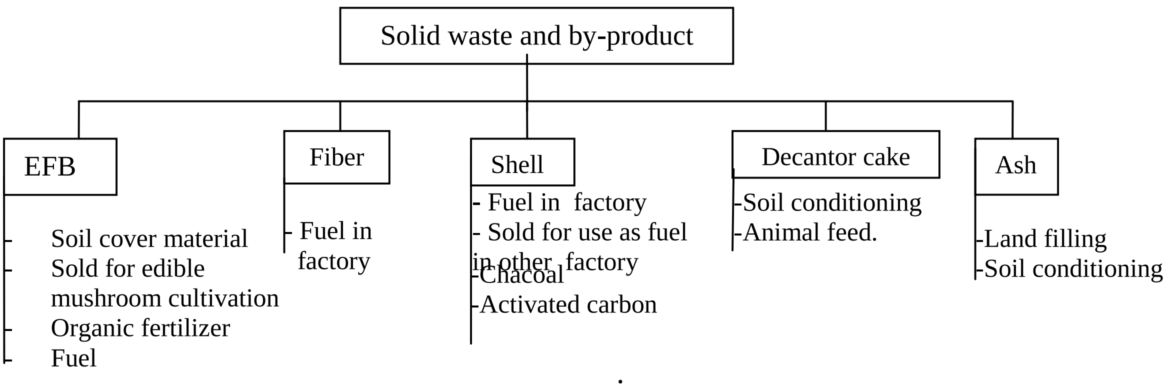

Figure 1. Alternative usage of solid wastes/ by-prouct from crude palm oil production.

4. Ecosystem in the crude palm oil industry

The crude palm oil industry has developed a number of ecosystems for its waste recycling. The nature of these ecosystems, divided as in-plant, cross industry and cross-border. The details are as following:

In-Plant Ecosystem

1) Recycling of fiber in boiler

Palm oil mills in Thailand operate a cogeneration system using biomass residue as fuel in boiler. The fiber and shell are burned in boilers to produce high pressure steam which is that expanded through a steam turbine to drive a turbo alternator, Steam is also used in the manufacturing process for sterilization, digestion purification and also control temperature in production process. The electricity generated is used to supply the mill's electricity requirement which was estimated as much as about 14.5 Kw for ton of fresh fruit brunch processed. In the mill proposed in this complex, 140 tons of fibers are burned to supplement the steam required in production. The fiber is burned in boiler produces 630 tons of steam for energy production. The steam can be used to generate 13,000 kw-h of electricity which can be used sufficiently in the mill.

2) ***Recycle of sterilizer condensate***.

After use for generate power, the steam is sent to sterilizer . Sterilizeation of FFB is done batchwise in autoclave of 20-30 ton FFB capacity. The quantity of sterilization condensateis about 0.12 m^3 /tonFFB. This wastewater can be recycle to screw press and vibrating screen in order to reduce hot water use in those process (Fig 2). Moreover the sterizer condensate contains about 1% oil which can be recycle into the process.

It is estimated that approx 0.12 m^3 /tonFFB could be saved by recycling this excess condensates at a 1,000 ton FFB factory at a capital cost of approx 3,000 EU for pumping, tank etc. This option can save water production cost about 2,400 EU per year (water production cost=66.7 EU/ 1,000 m^3 and based on operating days = 300 days/ year). Recover oil from recycle wastewater is about 1.4 liter/ ton FFB. Benefit from increase oil yield is 28,000 EU per year. Total profit for this option is 30,400 EU per year.

3) Recycle of solids (fiber).

The usual method of extracting crude palm oil from the digested fruit is by pressing. Crude oil flow to vibrating screen. The pressed oil is screened to remove course solids from the crude oil. These residual solids are recycled back to digester and then to screw press to recover oil.

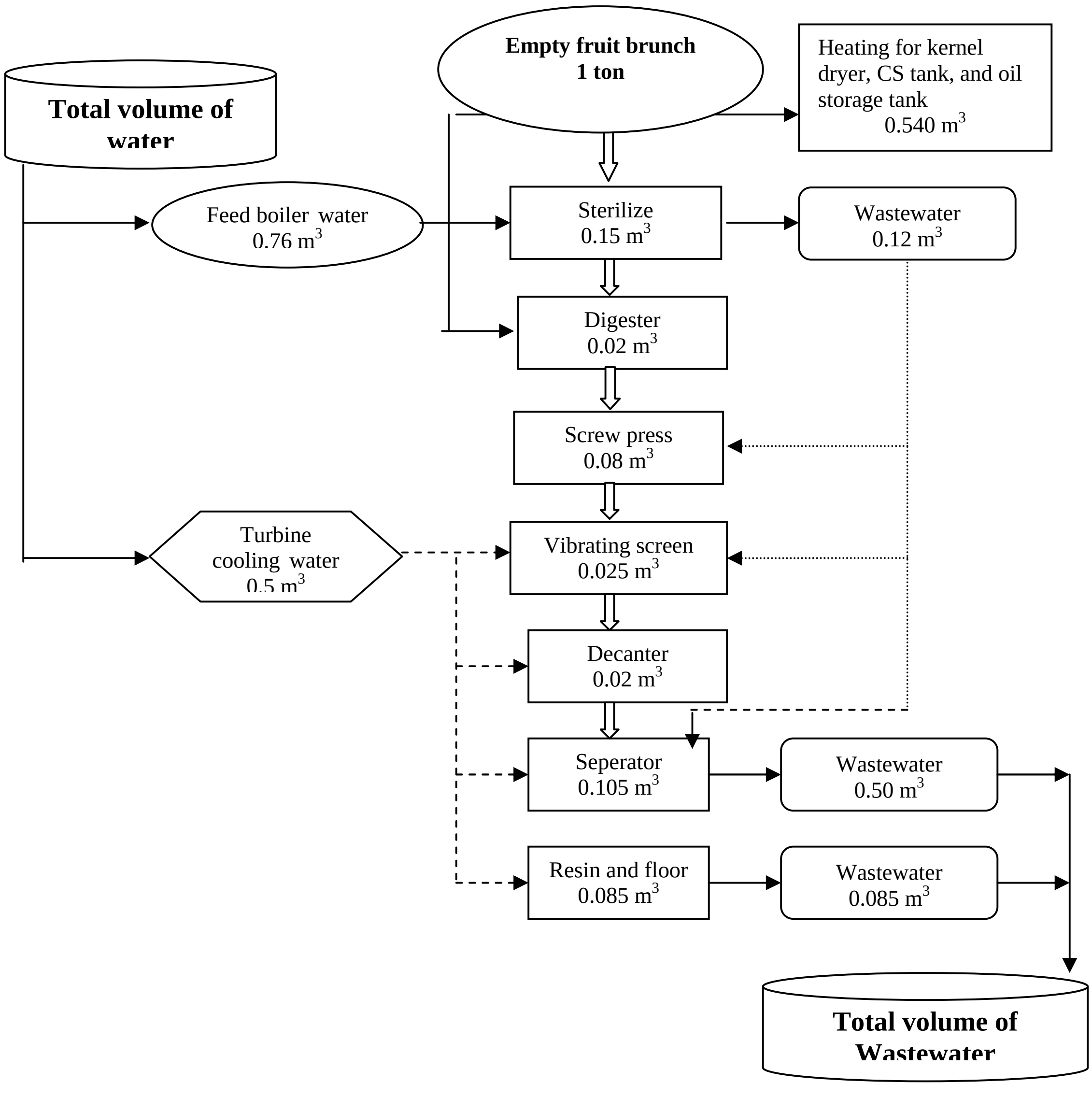

Figure 2. Flow diagram of production process and in-plant water recycle

4) ***Recycle of excess condensate***.

Some amount of steam is sent to kernel dryer silo and vacuum dryer of crude palm oil . Last stage condensate are generally discharge as wastewater due to oil contaminated in water. However these condensate can be recycle as feed boiler water and feed separator water. This option will reduce the amount of water consumption and wastewater generation. Addition benefit from this approach is energy conservation with save energy for heating water to 90 degree celcius (Fig 3). It is estimated that approx. 30 m^3 /tonFFB could be save by recycling the excess condensate at a 1000 tonFFB capacity.

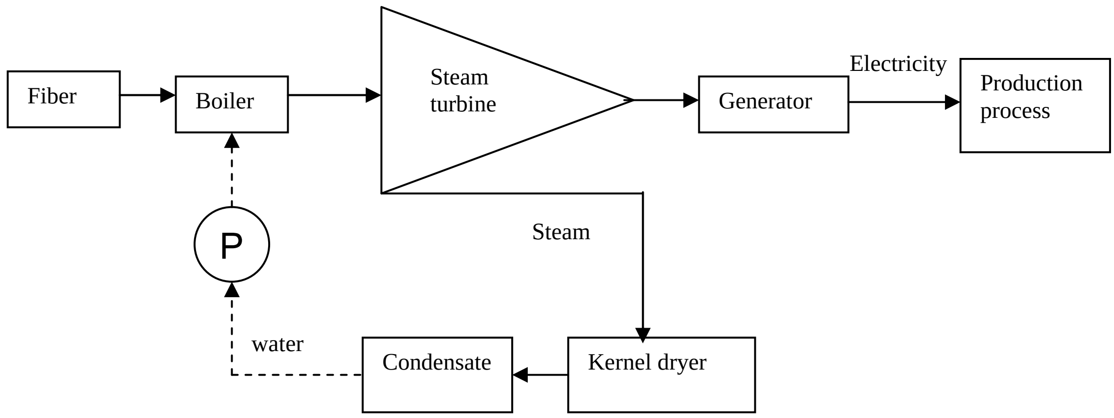

Figure 3. Recycle of condensate to boiler

Cross-industry Ecosystem

1) Empty Fruit Brunch (EFB) as a substrate for mushroom cultivation

In the crude palm oil industry, EFB is the largest volume of solid waste. Conventionally, it is returned back to the field as soil cover material. EFB can be used as covering material, organic fertilizer and soil conditioner in the plantation. However at present Mushroom grower including farmer use EFB to grown straw mushroom in the oil palm plantation area because EFB could be used directly as a substrate for mushroom cultivation. Mushroom 30 kg.(price 15 EU.) can be harvest from 1 ton of EFB. One ton of empty fruit brunch cost ~ 2.5 EU.After harvest the mushroom, EFB is available as substrate to the palm fertilizer.

2) Shell as fuel in cement factory

Shell can be used as boiler fuel (calorific value of 17 MJ/kg) in factory. However, fibers are more than enough to be used as fuel for boiler. At present shell can be sold to use as fuel in cement factory and brick factory. One ton of shell costs 11 EU. Another use of shell is the production of charcoal. Another possible use of shells is the production of activated carbon, which should need further investigation.

3) Decanter cake as animal feed

For mill using decanter to separate oil from sludge, the generated decanter cake can used as soil conditioner and fertilizer in palm oil plantation. Nowadays decanter cake can used as animal feed for cattle. Factory can use excess steam to dry decanter sludge before sold as animal feed.

4) ***Fly Ash as secondary resource***.

The boiler of crude palm oil factory uses fiber and shell (ratio 4:1) as the energy source. The fly ash of this biomass fuel is a mixture of SiO_2, CaO, K_2O, P_2O_5, MgO and Al_2O_3 (59.16, 8.0, 7.6, 4.74, 4.13 and 1.9, respectively). This fly ash can be used to directly replace Portland cement up to 10% by weigh. This is a high value-added application; provided its carbon content is less than 8.5% and its physical and chemical properties are reasonably stable.

Cross-Border Ecosystems

1) Empty fruit brunch as soil conditioner or fertilizer.

The empty fruit brunches are good source of organic matter and plant nutrients. Their chemical composition is shown in table 8. From this composition analysis, one ton of empty fruit brunch would have a fertilizer equivalent of 8 kg of N, 0,6 kg of P, 24.1 kg of K and 1.8 kg of Mg.

2) ***Palm oil mill Effluent (POME) as agricultural arrigation***.

Application of biologically treated POME for irrigation is a method used by many palm oil mills. Since the amount of Mg content in WW is very high, So volume of POME to be applied to oil palm tree is limited. Only 1.2 – 18 m^3 POME can be used per acre per year for oil palm plantation. It is clear from Table 8 that waste water after anaerobic treatment is suitable for oil palm irrigation because it is neutral (pH ~ 7.8) and still contain high N, P, K and Mg content. From calculation based on extraction of 300,000 tons of FFB/year. Nutrients content in WW after anaerobic treatment are equal to 57.5, 4.7, 33.6, and 336 tons of N, P, K and Mg respectively.

Table 8. Average nutrient contents in the residues of POME

residue	N	P	K	Mg	Quantity kg/ton FFB
EFB, k/ton drywater (30% moisture content)	8.0	0.6	24.1	1.8	240.0
Decanter cake ,kg /ton dry (70 % moisture)	20.0	8.0	2.0	4.0	42.0
Raw wastewater, kg/m^3.	1.1	0.047	0.1-0.3*	20*	630 m^3/ton/d
After anaerobic treatment, kg/m^3	0.34	0.028	0.1-0.3*	2.0*	
After full biological treatment, kg/m^3	0.03	0.003	0.1*	2.0*	
Nutrient from EFB application, tons/year	402	30	1230	90	
WW after anaerobic, ton/1000 ton FFB/ year	64.3	5.3	37.8	378	
Total	466.3	35.3	1268	468	

Note: * data from Kittikhun, A. et al 2000.

5. Environmentally balanced of crude palm oil industry.

The absolute optimum in waste minimization involves developing a system whereby no waste industry is discharged into the air or water, or onto the land. Environmentally balanced of these industries are simply a selective collection of compatible industrial plants located together in one are (complex) to minimize both environmental impact and industrial production costs. These goals are accomplished by utilizing the waste materials of one plant as the raw material for another with a minimum of transportation. When a manufacturing plant neither treats its wastes, nor stores or pre treats certain of its raw materials, its overall production costs must be reduced signify cantly.

An evaluation of the crude palm oil mill based on products and wastes suggested that a closed loop complex would result in the discharge of little or no final residual wastes. Figure 4. presents a schematic diagram of a crude palm oil mill, based environmentally balanced industrial complex. For purpose of this evaluation, the estimated mass balances are based on the extraction of 1000 tons of fresh fruit brunch, resulting in the generation of about 650 m^3 of wastewater, 240 tons of empty fruit brunch, 140 tons of fiber, 48 tons of shell and 42 tons of sludge from decanter.

It is clear that EFB, decanter cake and WW from crude palm oil mill contain high K, N, P and Mg content that can be use as fertilizer in oil palm plantation area. And calculation based on the extraction of 300,000 tons of FPP/ year, resulting in the nutrients contain in EFB are equal to 221, 16.8, 665 and 49.8 tons of N, P, K and Mg respectively. The detail of quantity of nutrient content in residue from crude palm oil mill is shown in table 9 For decanter cake, the quantity of N, P, K and Mg are equal to 90, 36, 9, and 18 tons/year. These residues are used as fertilizer to replace a portion of a commercial fertilizer needed in the plantation area to grow oil palm.

Table 9. Balance of fertilizer demand for oil palm plantation area

Fertilizer demand	N	P	K	Mg	B
Old palm tree, kg/acre/year	81.5	10.5	28	10.5	5.0
Oil palm tree ,tons/60,000acre/year	4,890	630	1680	630	300
Fertilizer from waste, ton/ year	466	35.3	1268	468	-
Commercial fertilizer, ton/ year	4,424	595	412	162	300
reduce commercial fertilizer (%)	9.5	5.6	75.4	74.3	0

Total waste is used as fertilizer to replace a portion of the commercial fertilizer needed in the plantation is shown in table 9. Since the EFB and WW may not contain all the requisite type and quantity of nutrients of a commercial fertilizer on a unit – weight basis. An appropriate amount of commercial fertilizer will be apply to plantation area to meet the necessary growth requirements, depending on age of oil palm tree. Approximately 60,000 acre of land are required for harvesting 300,000 tons of FFB as feedstock for extraction at a rate of 1000 tons per day.

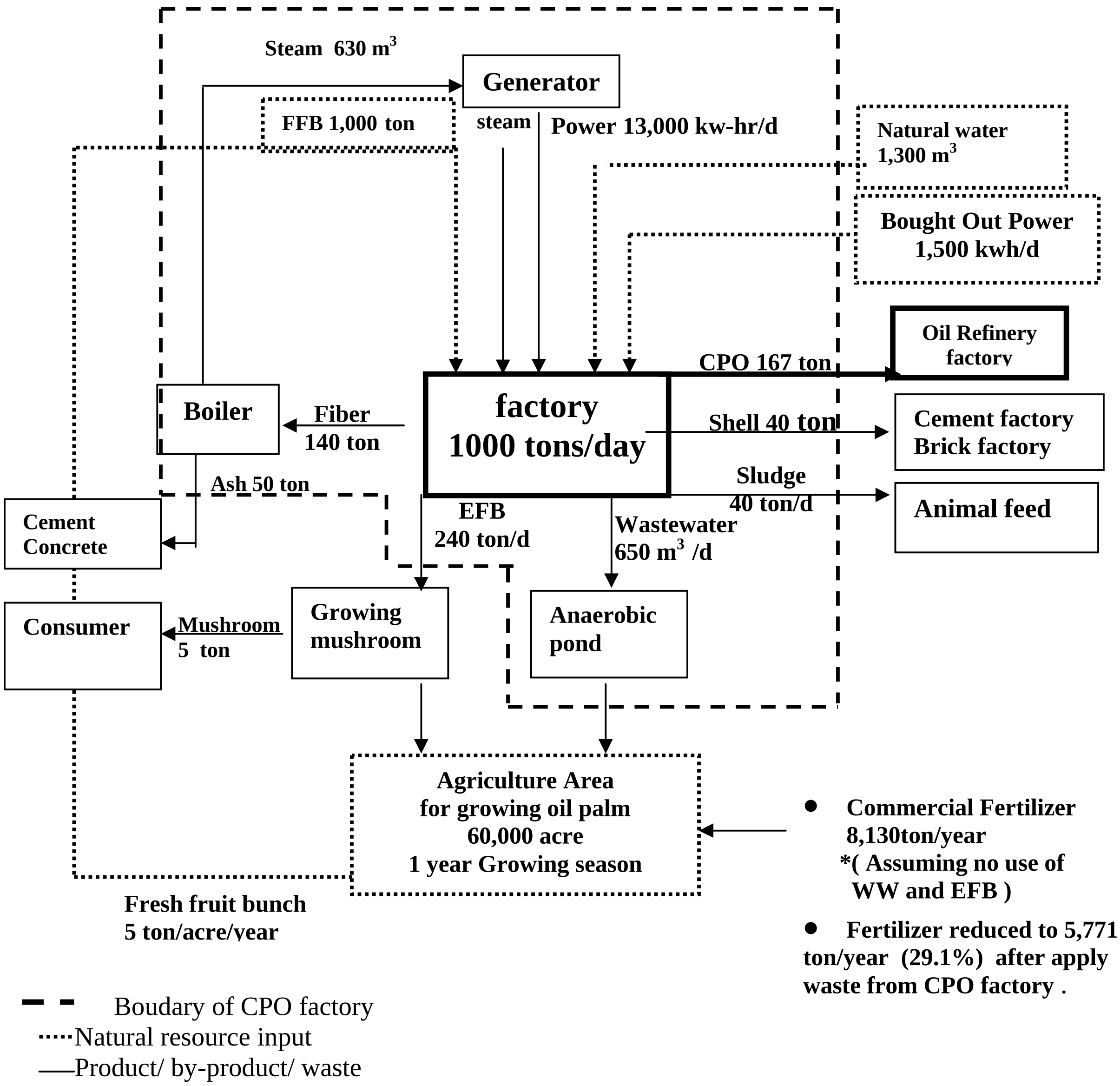

Figure 4. The environmentally Balance CPO industry solution

Conclusion

The crude palm oil mills generate many by-product and wastewater, which may have a significant impact on the environment if they are not managing with properly. Industrial ecosystem is needed for crude palm oil industry by reuse, recycle, and utilization of solids and liquid waste to achieve the goal of zero discharge concept. Then the palm oil mill will become an environmental friendly industry.

Reference

Allenby, B.R. and Richrds, D.J.1994. *The Greening of Industrial Ecosystems*. National Academy Press. Washing, D.C.

Allenby, B.R. and Graedel, T.E. 1995. *Industrial Ecology*. Prentice Hall, New Jersey.

Chao, C.C. 1999. Promotion and development of industrial eco-systems in Taiwan, R.O.C. *Pupliched in Proceeding of International Conference on Cleaner Production and Sustainable Development' 99*. Decemberrr 13-17, 1999. Teipei, Taiwan.

Kittikhun, a., Prasertsan, P., Srisuwan, G. and Krause,A. 2000.Environmental Management for Palm Oil Mill. Internet Conference on Material Flow Analysis of Integrated Bio-Systems. March-October 2000.

Liu, K and Shyng, Q. 1999. Eco-system in the steel industry. *Pupliched in Proceeding of International Conference on Cleaner Production and Sustainable Development' 99.* Decemberrr 13-17, 1999. Teipei, Taiwan.