CHAPTER 1

INTRODUCTION

1.1 Introduction to Palm Oil Industry

1.1.1 Historical Development of the World Palm Oil

Oil palm has its origin in tropical rain forest of West Africa, Where it had been used as source of oil and vitamin. It has been consumed for more than 5,000 years. Today the oil palm tree can be found in many tropical countries in Asia, Africa and Latin America. However the important areas of oil palm cultivation are Malaysia, Indonesia, Nigeria, Papua New Guinea and Thailand (as shown in Figure 1.1), the home of the oil palm tree now only produces about 15% of the world's palm oil while South East Asia produces about 80% (Gopal, 2001). Oil palm seed of Dura variety were introduced to Indonesia and Malaysia in 1848 and 1875 respectively. The first commercial oil palm plantation was established in Malaysia in 1917. The slump in rubber prices in the late of 1920s encouraged the cultivation of oil palm. At that time, Nigeria and Zaire were the world leading palm oil producers.

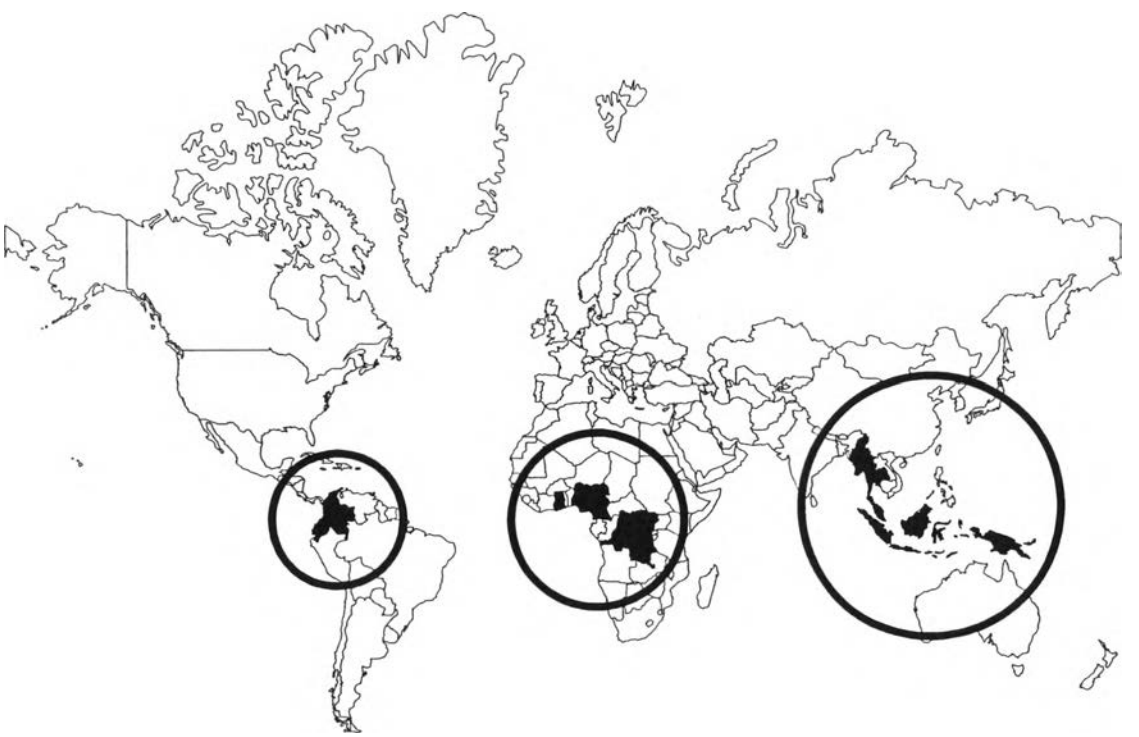

Figure 1.1 Map of the largest palm oil producing countries in the world (Zuur, 2004).

During 1960-1995, the palm oil industry in Malaysia showed a very rapid growth and it has been the world's leading exporter of palm oil since 1966. Malaysia has been the largest producer of palm oil since 1971, replacing Nigeria, which had been the major producer and exporter since the introduction of palm oil into the world market. Malaysia is currently the single largest producer with more than 50% of the world's production, while Indonesia follows with almost 30% of global production. Malaysia exports most of

its production, unlike Indonesia which consumes 60% of its annual products of palm oil. About half of the world palm oil production (10.8 million tones) was accounted for by Malaysia (MPOB, 2002). The world palm oil production during 1996-2000 is shown in Figure 1.2. Thailand is ranged fourth on gobal production of palm oil.

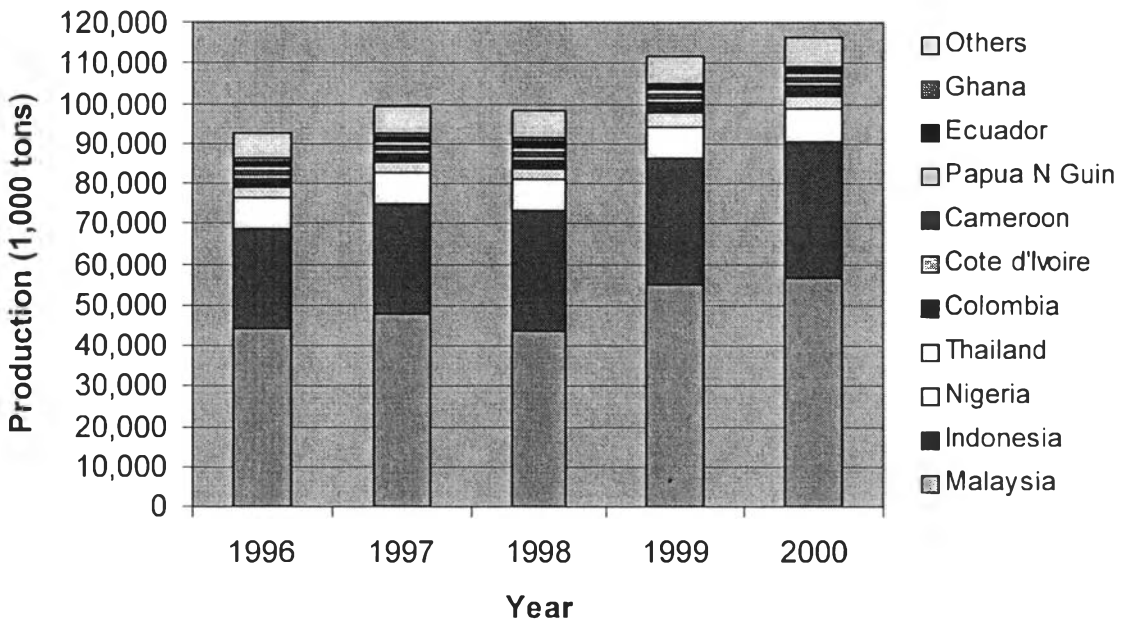

Figure 1.2 World palm oil production 1996-2000 (OAE, 2004; MPOB, 2004).

In global terms, since 1982 palm oil has become the second most important vegetable oil, after soybean oil, in the world's oil and fat complex. Of the world exports of major oils and fats, palm oil is the largest traded oil, accounting for 40% of world exports in 2001, the second oil with about 22% of global trade. World consumption of palm oil increased from 1990 to 2000 with 7.7 million ton per year, from 11.41 million in 1991 to 21.8 million ton in 2000.

1.1.2 Palm oil Product

The refined palm oil is used both for food and non-food applications. Starting with the first category, to most users, palm oil is familiar as fully refined golden yellow oil. Following a refining process palm oil can be divided in fractions that are liquid at room temperature or have higher melting point. Various grades of oleins and stearins are available commercially. Various food products use palm oil, such as cooking oil, margarine, frying fats, shortenings, vanaspati, non-dairy creamer, etc. The second category, the non-food products, competes with products derived from petrochemicals. Some examples of these non-food applications are given in Table 1.1. Palm oil based products are more environmentally friendly than petro-chemical alternativesand with the increasing awareness of environmental issues, these applications have a bright future.

Table 1.1 Non-food uses of palm oil products (from: MPOB , 2002).

Oleochemical	Application
Caprylic-capric acid mixture	Esters, surfactants
Caprylic acid (90%)	Plasticizers, lubricants
Caprylic acid (95%)	Chemical intermediates, etc.
Distilled palm kernel fatty acid	Surfactants, stabilizers, etc.
Lauric-myristic acid blend (70/30)	Surfactants, emulsifiers, stabilizers, textile
Lauric acid (90%)	Auxiliaries, esters, cosmetics
Double pressed stearic acid	Soaps, cosmetics,candles
Triple pressed stearic acid	Crayons, greases, monoglycerides, paper
Palmitic acid (70%)	Coating, buffing
Palmitic acid (90%)	Compounds, waxes
Stearic acid (65%)	Emulsifiers
Stearic acid – cosemetic grade	Rubber, etc.
Stearic acid – rubber grade	Surfactants, chemical intermediates, etc.
Oleic acid	Alcohols, alkanolamides
Methyl ester (C12-C18)	Detergents, metal, treatment
Fatty alcohol (C8-C18)	Detergents
Glycerine (99.5% purity)	Humectants, cosmetics
Glycerine (99.0%)	Esters, pharmaceuticals
Glycerine (99.5%)	Explosives, food, etc.
Soap noodles	Toilet soaps

1.1.3 Development of Palm Oil Industry in Thailand

Over the past decades, the Thai economy showed a sustained growth of over 8% per annum. The reason was a substantial expansion in both domestic and export markets. Agricultural and natural resource extraction, rapid industrialization, rapid and concentrated urbanization, as well as increasing income and consumption characterize this economic growth path. Unfortunately, this bubble economy has plunged down in 1997 during the so-called Asian financial crisis. Since then the recovery of the Thai economy has been the prime goal of each government. In expecting a positive contribution to sustainable economic growth, the Thai government promoted strongly the development of the SME sectors in late 1998. Being an agricultural country, agro-industry was obviously one of the key sectors for boosting the SMEs. The palm oil industry has played an important role in the Thai economy because oil palm thrives well in Thailand. Apart from that, palm oil accounts for as much as 62% of the vegetable oil market, estimated to be worth Baht 40,000 million per annum (Research Department, Bangkok Bank Public Company Ltd., 2001). Consumption of palm oil in Thailand is roughly 570,000 ton per annum, rising by an average 11 percent annually. It is estimated that in 2006 the consumption will be up to 718,000 tons. Palm oil is a commodity that has the potential to expand well in the future (Research Department, Bangkok Bank Public Company Limited, 2001).

The palm oil industry refers to the whole complex of agricultural and industrial activities that are directly linked to production of palm oil. The Thai palm oil industry has had a relatively late start in 1968, some 50 years behind Malaysia and 57 years after

Indonesia. This industry began to actively expand when the government granted promotion to the private sector to set up palm oil extracting factories in order to process oil palm fruits, the output of which was rising rapidly. Promotion was, moreover, given to produce palm oil to substitute for imports in 1974. Then in 1977, the Board of investment granted investment promotion to the establishment of palm oil extracting and refinery industry.

During 1975-2000, the palm oil industry in Thailand showed rapid growth (Table 1.2). Since 1995 the area of Thailand under oil palm cultivation has more than doubled to 0.17 million hectare. Under the government's current five-year plan the area was doubled again to 0.28 million hectare in 2001 (Figure 1.3). In the southern part of Thailand, particularly Krabi, Surat Thani, Chumphon, Trang and Satun are important in palm growing. Fresh fruit bunches have to be harvested and transported to factories and have to be extracted within 24 hours. Otherwise the quality of extracted palm oil will deteriorate. Given this fact, the factories have to be located close to the palm growing areas. Crude palm oil supplied by extracting factories has to be refined to obtain pure palm oil suitable for consumption or for use as raw material by the downstream industry. The palm oil, which undergoes the refining process, is called RBD oil (refined, bleached and deodorized oil). Currently, there are altogether 26 crude palm oil mills and 11 refining factories in Thailand. Most of refinery factories are set up in Bangkok and its environment, because the important market for palm oil is in the central region. At present, the production capacity is 1 million tons of crude palm oil/year.

Table 1.2 Thailand: Palm Oil Industry-Basic Statistics (Ministry of Agriculture and cooperatives, 2003).

Year	Plantation Area (x1000 ha)	FFB Yield (Tons/ha)	CPO Production (x1000tons/ year)	CPO Yield (tons/ha)	Price of FFB (Bath/kg)	Price of CPO (Bath/kg)
1970	0.2	-	-	-	-	-
1975	5.6	-	-	-	-	-
1980	36.3	9.62	-	-	-	-
1985	82.2	11.43	205	1.88	-	-
1990	140.1	12.43	217	1.55	1.89	12.49
1995	168.1	13.09	403	2.39	2.05	15.87
2000	257.6	13.53	640	2.48	1.66	12.79
2001	280.0	17.86	1,000	3.57	1.19	10.70
2002	233.0	17.54	800	3.40	2.30	16.25
2003	244.0	16.50	844	3.46	2.35	17.83

Note: 1 hectare = 6.25 rai

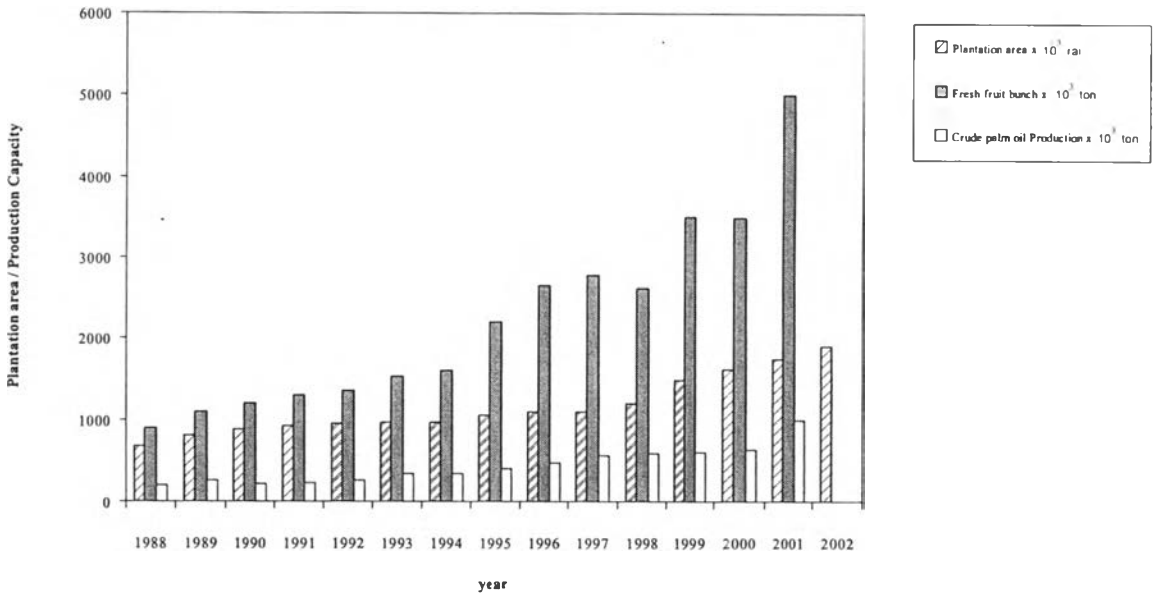

Figure 1.3. Plantation area and production capacity of crude palm oil in Thailand (Ministry of Agriculture and cooperatives, 2003).

1.1.4 Thailand Trade of Palm Oil

Prior to 1982, the quantity of import palm oil in Thailand was depended on the price in the world market and the domestic costs in palm oil industry. The expansion of import has increased rapidly from 5.4 million Baht in 1975 to 836 million Baht in 1980 due to the fact that price of palm oil in world markets was much lower than the domestic price. Most of imported palm oil came from Malaysia in the form of RDB palm oil.

To protect CPO industry in Thailand, the government imposed a high tariff wall and restricted control of imported palm oil products in 1982. After that import of palm oil has declined as shown in Table 1.3. In last few years, the value of import increased again due to shortage of CPO in dry season. Major types of palm oil imported are hydrogenated palm oil and CPO. Hydrogenated palm oil is use as raw material in many industrial processes.

Table 1.3 Quantity and value import and export palm oil in Thailand (Ministry of Commercial, 2004).

Year	Export		Import	
	Quantity (x1000 tons)	Value (million Baht)	Quantity (x1000 tons)	Value (million Baht)
1975	-	-	-	5.4
1980	-	-	-	836.0
1985	-	-	-	97.0
1990	-	-	19.4	57.0
1995	13.8	224	20.5	340.0
2000	87.0	1,168	18.4	496.0
2001	222.0	2,376	1.9	2.0
2002	113.7	1,863	2.6	53.9
2003*	152.0	2,757	-	-

Note: * value from January to September 2003

Since the cost of palm oil in Thailand is higher than in for instance Malaysia and not competitive to the world market, palm oil export is low. The quantity and value of export of palm oil is about 5% of total production. The value of export has increased to 2,757 million Baht in 2003. The major exports markets are Malaysia, India and Burma. The major types of palm oil product are modified, hydrogenated palm oil. Within the Asean Free Trade Agreement palm oil is one of the 15 fast track industrial products, the tariff rates on which have to be reduced rapidly while control and protectionist measures have to be removed in keeping with AFTA. However, the Thai authorities have the opinion that Thai palm oil producers are still in a considerable disadvantage against their Malaysian and Indonesian counterparts. They have, therefore, requested to remove this item from the fast tract list of commodities and enter them in the temporary exclusion list. This will allow Thailand more time for restructuring the industry. But After 2003, the tariff rates will be brought down to 0-5 percent in 5 years coming from 20% . When the Thai palm oil market has to open up to foreign competition, palm oil industry will be strongly affected because the production costs of Thai crude palm oil are higher than Malaysia's (Figure 1.4).

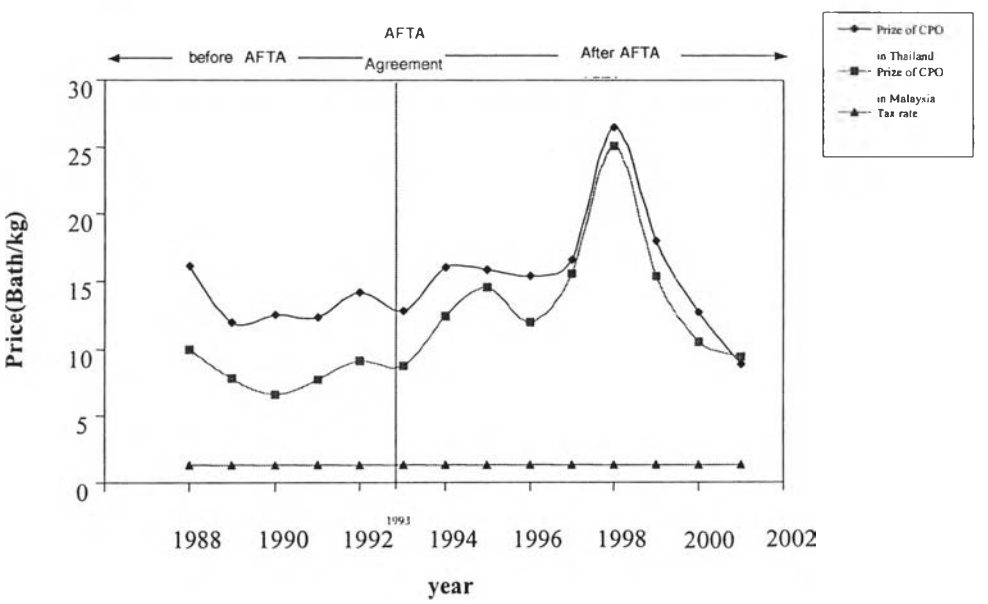

Figure 1.4 The price of crude palm oil in Thailand compared to Malaysia.
Note: 1 U$ = 41 Bath.

1.1.5 Comparison of Production Technology between Thailand and Malaysia

The advantage Malaysian in palm oil industry sector is the suitable condition for oil palm cultivation such as climate and many of soils condition (Gopal, 2001). Moreover MPOB do research and development to improve oil palm breed (high oil content) and good management of plantation system (Yusoff, 2004). The current average yield is 18-25 ton of FFB/ hectare/ year. In Thailand the average yield of plantation is 16.5 ton of FFB/ hectare/ year. The efficiency of FFB production and oil yield per hectare of Thai oil palm plantation are lower than Malaysia 10% and 20%, respectively (Table 8.1). Since low amount of oil content in Thai FFB, crude palm oil production efficiency of Thai miller is 11 % lower than Malaysia's. Table 1.4 shows the comparison of crude palm oil production efficiency between Thailand and Malaysia.

Table 1.4 Comparison of CPO production efficiency between Thailand and Malaysia.

	1 ha of mature palms (t/ha/year)	
	Thailand[1)]	Malaysia[2)]
No. of standard crude palm oil mill	25	352
Production capacity, million ton/year	0.8	17.4
FFB production, ton/ha/year	17.5	18.33
Oil yield, ton/ha/year	3.4	3.46
Oil content in oil palm fruit, %	17	23
Oil extraction, %	16.8	18.7

Note; 1) Ministry of Agriculture and Cooperative (2002)
2) Yusoff, 2004

1.2 Environmental Pollution of Crude Palm Oil Industry

The extraction of palm oil from fresh fruit branch involves 5 major operations - fruit separation and loosing, sterilisation, digestion, oil extraction and oil purification (Taiwo, et.al., 2000). There are 2 types of palm oil mills: dry processing mills and wet processing mills. Among the 50 crude palm oil mills, 26 factories are utilizing standard wet production processes. The wet process differs from the dry process with respect to the oil extraction stage: the wet process applies large amounts of hot water and steam to convert palm fruits into a homogeneous oily mass before feeding them into the continuous screw press to extract palm oil (Kittikun, 1997). The entire crude palm oil process does not need any chemical as processing aid. Therefore, all substances found in the products, by-products, and residues originate from the fresh fruit bunch. However, there are number of pollution problems at the facility, such as high water consumption, generation of high organic content of wastewater, generation of large quantity of solid waste and air pollution.

Wastewater is a thick brownish colloidal slurry of water, oil and fine suspended solids. Results of wastewater analysis from palm oil mills indicate high quantities of oil and organic substances as the main contaminants, as shown in Table 1.5 (Setiadi, et al.,1996). Severe environmental deterioration is caused by the discharge of palm oil mill effluent (POME) into watercourses. From calculations, the waste generated from Thai palm oil mills are equivalent to waste generated by 3 million people in 1996 (Kittikhun, 1997). Thus, it can be concluded that POME poses a serious threat to the environment and the quality of life in rural areas, unless proper pollution measures are taken.

Table 1.5 Characteristics of raw wastewater and effluent from crude palm oil mills in Thailand and Malaysia.

Parameter	POME		Effluent		Effluent Standard	
	Thailand(1)	Malaysia(2)	Thailand(1)	Malaysia(2)	Thailand	Malaysia(2)
pH	4.8	4.2	6.8 - 9.6	7-8.4	5-9	5-9
BOD, mg/l	26,000	25,000	6 - 195	40-503	20	100
COD, mg/l	70,000	50,000	142- 2970	1194-2000	120	-
SS, mg/l	13,000	18,000	11 - 322	301-1100	50	400
Oil, mg/l	11,527	6,000	1- 232	51-92	5	50

Source: (1) Survey study in 2002 and (2) PORIM, 2001

Palm oil mills employ conventional biological treatment system to treat their POME. The systems comprise of anaerobic and aerobic or facultative processes. 64 % of

palm oil mills use anaerobic and facultative ponds in series. The alternative treatment options for POME are anaerobic and aerobic lagoon in series (29 %) or anaerobic digestion tank and facultative ponds in series (7 %). It has been observed that nearly all mills in Thailand cannot treat their wastewater to meet the effluent standard. Therefore, such wastewater is kept in ponds without discharge. Moreover the Department of Industrial Work does not allow any mills to drain their effluent to watercourse, because the color of wastewater will effect consumption of water in canal downstream. Problems of environmental impact from POME usually occur in rainy season, especially with mills, located close to communities and / or mill that do not own an oil palm plantation not own the oil palm plantation. The overflow from wastewater treatment plant causes heavy water pollution to the waterway. When discharged into watercourses surface water gets polluted and dissolved oxygen in the water will be depleted, affecting aquatic life and making surface water unsuitable for consumption.

Solid waste and byproducts generated in the palm oil extraction process are empty fruit bunches; fibers; shell; decanter cake and ash from boiler. Only 23.2 % of raw material are products (CPO and CPKO). The remaining part is by-product and waste. Most of these by-products can be reused in production processes or in other industries. Fibers (14%) can be reused as fuel in boilers. Shell (6%) and empty fruit brunch (EFB) (24%) is sold to use in other industry. However there is a lot of waste that has to treat properly before disposal. This waste includes ash (5%), decanter sludge (3.2%) and wastewater. Figure 1.5 shows 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.

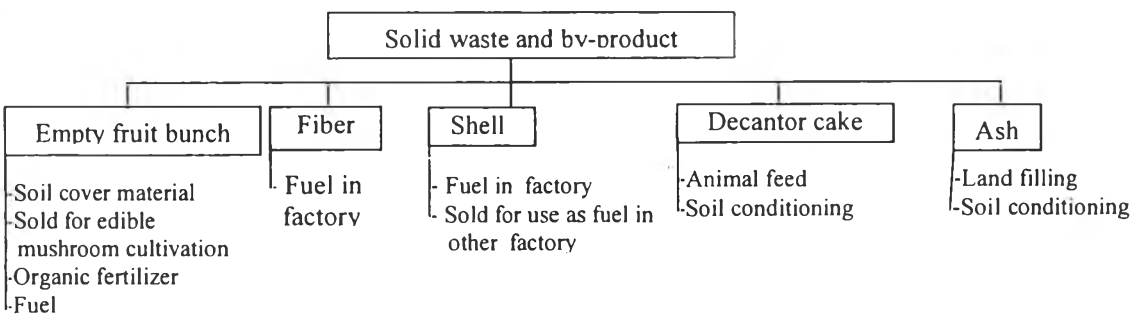

Figure 1.5 Palm oil solid waste applications.

Particulates and smoke are generated from burner/boiler in wet process factories due to incomplete combustion of 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 that are used as solid fuel in the steam boiler. In order to avoid problem with near by communities and local authorities, all mills employ cyclone as air pollution control equipment for particulate removal. Another problem for mills located nearby communities is bad smell from poorly managed effluent treatment system. All CPO mills employ anaerobic pond systems to treat their wastewater. But POME contains high grease and oil contented which cannot decompose by anaerobic bacteria. They accumulate and cover the surface of the pond and cause odor emission

1.3 Environmental Protection development of Thai Crude Palm Oil Industry

1.3.1 End-of-pipe approach

The current regime of (water) pollution control in Thailand follows a command and control approach. The majority of legislation focuses on end-of-pipe approaches to pollution control. This approach has been successful in raising awareness on environmental issue among industrialists but government is facing difficulties in law enforcement and compliance (White, 2001). To avoid problems with community and local authority, crude palm mills improve their environmental performance by improve their wastewater treatment plant such as construct more pond to keep wastewater and disposal solids waste everyday. Most POME treatment plants have been constructed to meet a BOD concentration limit. This effluent BOD limit is achievable if the treatment systems are well designed and operated. Nevertheless, it is observed that not all-crude palm oil factories can treat their wastewater up to the level that to meets the effluent standard at all time. In practice, medium-sized crude palm oil industry has difficulties dealing with their environmental especially problems (Gombult,1999).

1.3.2 Cleaner Production Approach

In general, the best way to reduce the impact of waste is to reduce the amount of waste that needs treatment or disposal. The crude palm oil mills can reduce environmental impacts through the implementation of pollution prevention measures, also known as cleaner production options. These measures can also result in decreasing costs of production (Jeswani, 2001). The cleaner technology concept is not new to crude palm oil industry in Thailand. Since 1994, the Department of the Industrial Works has been actively promoting the cleaner technology concept. Experiments have been done in the Thai crude palm oil industry with assistance from international donor agencies and experts. These experiments have introduced and prepared environmental management guidelines for crude palm oil industry, and have introduced cleaner technologies to crude palm oil industry: reducing wastes, improving their utilization and improving their treatment (The Department of Industrial Works, 1999). Between 1999 and 2001, the promotion of cleaner production has been implemented in crude palm oil industry through the support of government and international donor agencies. Universities, Research institutes, NGOs, and government agencies undertook some cleaner production projects. Crude palm oil industries have implemented cleaner technologies through these various joint projects. The result is an increasing number of mills that implement cleaner technology. Data from a survey shows that 75% of all factories are engaged in cleaner technology in year 2002. Most of options found were not technical ones, but good housekeeping and organizational approaches (Chavalparit, 2003). At the moment there are many agencies working on promoting cleaner production adoption in crude palm oil industry. Although there are obvious environmental and often also economic benefits in implementing cleaner production strategies, cleaner production can and often does entail investment. Optimum use of resources, good house keeping and recycling normally do not invest high costs, but cleaner production equipment and process modifications do.

1.3.3 Development in Environmentalism: industrial ecosystem

End-of-pipe treatment is sometimes unavoidable and necessary to minimize environmental burden. By means of cleaner production it is tried to minimize waste streams at the source. Industrial ecology on its turn tries to find an appropriate reuse for

the streams. The idea of industrial ecology is to first understand how the industrial system/metabolism works and than to restructure it into a sustainable industrial ecosystem. Although cleaner production is already a more integrated approach than end of pipe solutions, it still is restricted to only one process. In industrial ecology, an industry with its relations to other industries and actors is considered as an industrial ecosystem. During the last decade, environmental researchers began focusing on cleaner production/ waste minimization and even a new academic discipline, industrial ecology, was born with the mission to design zero-emission industrial processes (Aryes and Simonis,1994; Graedel and Allenby, 1995; Allenby, 1999). In this ecosystem, the waste from one process can serve as raw material for the other ones. Industrial ecology is an attempt to model the industrial system after the natural ecosystem, wherein the industrial processes are regarded as an industrial type of metabolism. The concept of industrial ecology emphasise the ideas of reduce/ reuse/ recycle and reclaim to advance sustainable industrial systems. The goal is to achieve optimize resource consumption and minimize waste discharge to the environment.

1.4 Research Objectives

The aim of this study is to assess the potential contribution of clean(er) technology to improve environmental performance of crude palm oil industry in Thailand, to analyze implementation barriers for cleaner production and to develop strategies to overcome these barriers. The specific objectives of this study are as follows:

- To evaluate the existing environmental performance of the crude palm oil production process in Thailand.
- To assess the feasibility of clean technology to crude palm oil industry by using optimal process-integrated management and technological options to improve the environmental performance of crude palm oil industry in Thailand.
- To identify and analyze the factors, actors, and barriers for the introduction of clean technology options in crude palm oil factory.
- To develop strategies for improving the environmental reform of crude palm oil industry by lifting the barriers for adoption/ implementation of cleaner production activities in industry.

1.5 Structure of Thesis

The thesis is divided in to eight chapters. The first chapter has an overview of crude palm oil industry development in Thailand, its environmental impacts and environmental protections, research objectives and the structure of this thesis. In chapter 2, a theoretical background is presented on the origination. The development and aspects of correlating theories that are dealing with sustainability and that are applicable to industrial processes are described. Discussions focus on ecological modernization theory and technological innovation including end-of-pipe treatment, cleaner production, and industrial ecology concept. The advantage and disadvantage of each approach are analyzed. It appears that all these theoretical approaches aim at environmental protection by reduction of resource consumption and minimization of waste emission, but the focuses differ from each other. Therefore, integrating these approaches into a broader perspective, to which they should be subordinated, could be a promising approach for

pushing industrial systems toward more sustainable ones. Chapter 3, a methodology of this study, presents on how to develop an integrated various theories from chapter 2 for an industrial system. A systematic methodology to develop a physical-technological model to move an existing industrial system toward a zero waste industrial ecosystem is elaborated in detail followed by a feasibility analysis in terms of actors and institutions. A selection of research strategy and research units as well as methods of data collection and analysis is also explained and briefly described in this chapter. Chapter 4 gives a review on environmental management of industry in Thailand. Environmental institution and actor and environmental legislation dealing with crude palm oil industry are discussed. Chapter 5 and 6 are dealing with case studies to test the approach and its suitability for greening crude palm oil industry in Thailand. The business of various five palm oil mills in Thailand was selected for more detailed analyses on the dynamics of clean technology development and introduction. The differences in production processes and locations are taken as core selection criteria. Each chapter focus in the different material streams towards, within and from this palm oil mill was used to determine the environmental implications of the process, followed by a study on the material balance, a zero waste ecosystem development. Then the possible technological solution to improve the environmental performance of the mill is investigated. These solutions will contribute to make parts of the process more efficient or reduce the environmental burden. Chapter 5 is devoted to study in details on one specific palm oil factory that situated closed to community represents the best practice in clean technology options at present in Thailand and a physical –technological model of a zero waste industrial ecosystem was analyzed. The rest four case studies present in chapter 6. Chapter 7 a triad network analysis is executed on the palm oil industry in Thailand to create a complete overview. The role of the different actors of the economic, political and societal network on the business of the palm oil mill including their relationship between these actors and internal actors within the company are clarified. Chapter 8, the final chapter, comprises the conclusions and the strategies for improving the environmental reform of crude palm oil industry in Thailand.