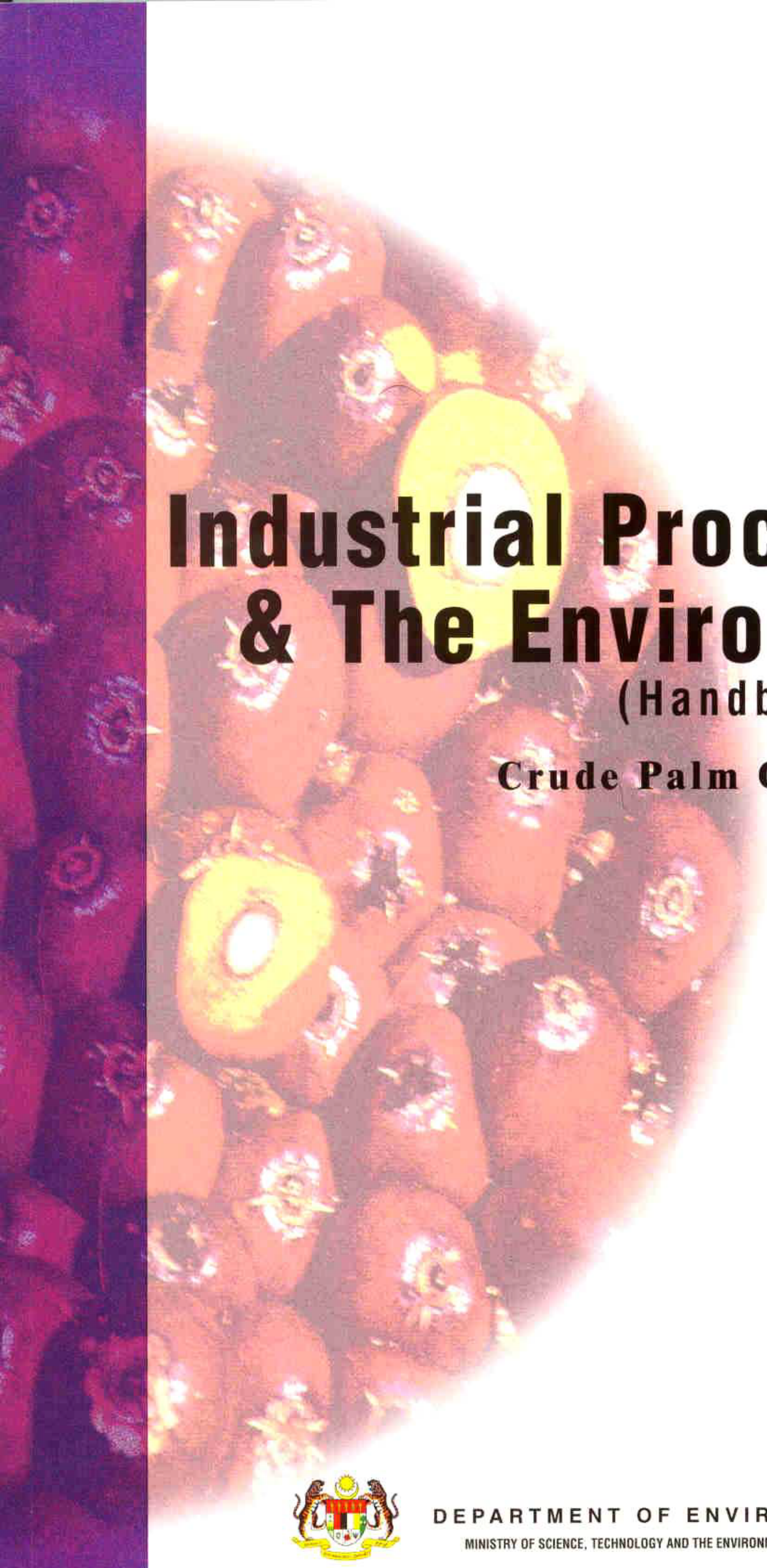

Industrial Processes & The Environment

(Handbook No. 3)

Crude Palm Oil Industry

DEPARTMENT OF ENVIRONMENT

MINISTRY OF SCIENCE, TECHNOLOGY AND THE ENVIRONMENT, MALAYSIA

Industrial Processes & The Environment (Handbook No.3)

Crude Palm Oil Industry

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FOREWORD

There is present global recognition that environmental protection demands need not impede industrial growth and expansion, and on the contrary can assure increased business competitiveness; this certainly holds true for industries that adopt the more sensible approach of efficient resource use based on cleaner production technologies. Thus, end-of-pipe solutions should rightfully be left to the last resort. In order for environmental agencies and authorities to be in a position to catalyse industry-adoption of cleaner technologies they have had to initially expand their knowledge-base and keep abreast of the rapid current developments taking place in the field of cleaner industrial production.

The Department of Environment (DOE), in also recognising this need, embarked on the preparation of a series of industry-specific environmental management handbooks within its on-going capacity-building project with support from the Danish Cooperation for Environment and Development (Danced). These handbooks aim at providing DOE Officers with adequate technical knowledge of specific industrial processes and pollution control technologies that would enable them to steer industry towards adoption of more efficient waste management and cleaner production technologies. As an integral part of this effort, the DOE is implementing dialogue/consultation sessions with various groups of individual enterprises. This stems from the realisation that the act of policing should not be the only means to enforce the Environmental Quality Act, 1974, rather it should go hand in hand with a process of consultation with the industries to bring about the desired level of regulatory compliance.

This Handbook on Industrial Processes & The Environment: Crude Palm Oil Industry is the third handbook in the series of publications. In the course of preparation, extensive discussions have been held with appropriate industry representatives to ensure that the technical information and suggestions presented in the Handbook are both current and of practical value. Through this effort, it is my sincere hope that the future compliance-monitoring activities of the DOE with respect to the palm oil industry will be more efficiently performed. It is also our desire that the technical contents will prove beneficial to palm oil producers in their endeavour to comply with the environmental regulations and standards through more cost-efficient means.

Hjh. Rosnani Ibarahim

Director General of the Environment, Malaysia.

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GLOSSARY

The following are definitions of the common terms used in this Handbook.

Aerobic	:	A condition in which "free" (atmospheric) or dissolved (molecular) oxygen is present in the aquatic environment.
Algae	:	Microscopic plants which contain chlorophyll and live floating or are suspended in water or attached to structures. Algae produce oxygen during sunlight hours and use oxygen during the night hours.
Anaerobic	:	A condition in which "free" (atmospheric) or molecular (dissolved) oxygen is not present in the aquatic environment.
Biodegradable	:	Organic matter that can be broken down by bacteria to more stable forms which will not create a nuisance or give off foul odours.
Biodegradable Organics	:	Composed principally of proteins, carbohydrates, and fats.
Biomass	:	A mass or clump of living organisms feeding on the wastes in wastewater, dead organisms and other debris.
BOD	:	Biochemical Oxygen Demand. The rate at which organisms use the oxygen in water or wastewater while stabilising decomposable organic matter under aerobic conditions.
BOD_3	:	Refers to the 3-day biochemical oxygen demand.
Clarifier	:	Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time during which the heavier solids settle to the bottom and the lighter materials float to the water surface.
Cleaner Production	:	An approach to production and manufacturing that focuses on source reduction, waste minimisation, energy efficiency and low-waste and non-waste technology.
Coagulation	:	The clumping together of very fine particles into larger particles caused by the use of chemicals (coagulants). The chemicals neutralise the electrical charges of the fine particles and cause destabilisation of the particles. This clumping together makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.
COD	:	Chemical Oxygen Demand. A measure of the oxygen-consuming capacity of organic matter present in wastewater.

Counter-current	:	Two different media moving in opposite directions of each other.
Crude Palm Oil	:	The primary liquid product from a palm oil mill
Depericarper	:	Equipment to remove the harder outer covering layer of the palm oil fruit
Detention Time	:	The time required to fill a tank at a given flow rate or the theoretical time required for a given flow of wastewater to pass through a tank.
Effluent	:	Wastewater or other liquid - raw (untreated), partially or completely treated - flowing from a reservoir, basin, treatment process, or treatment plant.
Empty Fruit Bunch	:	The bare fruit bunch after stripping of the fruitlets
End-of-pipe	:	Waste management solutions that are applied to the waste at the point of emission or discharge.
Facultative	:	Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulphate or nitrate ions. Facultative bacteria can live under aerobic or anaerobic conditions.
Fresh Fruit Bunch	:	The harvested palm fruit bunches with attached fruitlets
Kernel	:	The innermost softer part of the palm oil fruit
Mesocarp	:	The fleshy middle layer of the palm oil fruit from which palm oil is extracted
Mulching	:	Shredding leaves and wood material and spreading around growing plants
Neutralisation	:	Addition of an acid or alkali to a liquid to cause the pH of the liquid to move toward a neutral pH of 7.0.
Noxious	:	Substances that are harmful to human beings and have deleterious effects on human health and well-being due to their toxic and hazardous properties.
Potash	:	Potassium compound obtained from ashes

1.0 ABOUT THIS HANDBOOK

1.1 BACKGROUND

As part of its capacity-building effort in the area of industrial pollution control, the Department of Environment (DOE) has initiated the preparation of various industry-specific environmental management handbooks. These handbooks, which will contain comprehensive industry process and waste management information, are being developed for major Malaysian industry sectors and with relevance to the industrial situation in Malaysia, as well as the Malaysian context of environmental management and pollution control.

This Handbook is the 3rd in the series entitled Industrial Processes & the Environment. The five (5) industry-specific information handbooks initially identified for preparation are as follows:

- *Industrial Processes & The Environment (Handbook 1):*

  Metal Finishing – Electroplating

- *Industrial Processes & The Environment (Handbook 2):*

  The Raw Natural Rubber Industry

- *Industrial Processes & The Environment (Handbook 3):*

  The Crude Palm Oil Industry

- *Industrial Processes & The Environment (Handbook 4):*

  The Textile Industry

- *Industrial Processes & The Environment (Handbook 5):*

  The Food Industry

1.2 TOOLS FOR ENFORCEMENT

The DOE Manual on Practical Enforcement earlier prepared, and this series of industry-specific environmental information handbooks, are together aimed at serving the DOE as supporting enforcement tools to enhance the quality and effectiveness of its enforcement activities under the Environmental Quality Act 1974 (EQA). Thus, the Enforcement Manual and the industry-specific handbooks are designed to complement each other in terms of the information which they provide, and as enforcement tools are intended to broaden and strengthen the scope of the Department's enforcement functions and activities.

1.3 OBJECTIVES OF THE HANDBOOK

The objectives of this Handbook are to assist DOE Officers to:

- Enhance their knowledge of the crude palm oil industry, the production processes for crude palm oil, and cleaner production approaches for more cost-efficient waste management and pollution control;
- Conduct on-site inspections more expeditiously and effectively; and
- Disseminate information on cost-efficient waste management technologies, based on pollution prevention and cleaner production approaches.

However, the Handbook may also serve directly as a tool for providing information from DOE to the owners and operators within the crude palm oil industry. In this way, it aims to:

- Increase the awareness on environmental issues and potential impacts;
- Change the attitude towards better compliance and housekeeping; and
- Highlight the advantages and opportunities of cleaner production and technologies.

To help accomplish the above objectives, the Handbook specifically provides technical information on:

- The palm oil industry and the production process(es) for crude palm oil(CPO);
- Related environmental issues;
- The requirements of the Environmental Quality Act 1974 and subsidiary legislation pertinent to the crude palm oil industry;
- The current environmental management practices of the industry; and
- Cleaner production approaches and cost-efficient end-of-pipe solutions that can help the industry maintain its business competitiveness while meeting the desired environmental goals.

This Handbook is therefore a source of basic technical information on the crude palm oil industry (crude palm oil production) and its environmental management issues. It does not cover the downstream manufacturing activities, that is, the production of palm kernel oil (palm kernel crushing), or the refining of crude palm oil (production of palm stearin, palm olein, and/or other refined products), or the oleo-chemical manufacturing industries.

1.4 STRUCTURE AND CONTENTS OF THE HANDBOOK

There are eight (8) sections in this Handbook, the contents of which are as follows:

Section 1: General information about the Handbook.

Section 2: An overview of the crude palm oil industry in Malaysia, highlighting its historical past and present status.

Section 3: Brief description of the various processes involved in the production of crude palm oil and an identification of the sources of pollution.

Section 4: A highlight of the environmental issues of the crude palm oil industry, including wastes ordinarily generated and their respective waste characteristics.

Section 5: Regulatory framework and requirements of specific importance for the crude palm oil industry.

Section 6: Pollution control practices of the crude palm oil industry, including in-plant waste minimisation and housekeeping measures, available end-of-pipe technologies, and air pollution control measures for palm oil mills.

Section 7: Pollution prevention approach, including waste minimisation and cleaner production technologies.

Section 8: Suggested areas of inspection focus, essentially to guide DOE officers on what to look for during an inspection of palm oil mills to ensure effective enforcement.

Oil Palm Estate

Oil Palm Tree

Palm Oil Mill

2.0 THE CRUDE PALM OIL INDUSTRY – AN OVERVIEW

2.1 GENERAL PERSPECTIVE

The overall development of the oil palm sector in Malaysia is best described as having been most colourful. Oil palm was first introduced to Malaysia (then Malaya) in 1875. Early interest in oil palm was as an ornamental plant, and from about 1917 onwards the oil palm sector began its development into what is witnessed today as a multi-billion Ringgit industry. In its native Africa, this tree crop originally existed in the wild with the oil palm groves posing various constraints in man's effort to domesticate it as a planted tree crop. Malaysia has one of the most ideal climatic conditions for growing oil palm, and it is in Malaysia that the crop's full potential has been realised and exploited.

2.2 RAPID GROWTH OF THE PALM OIL AGRO-INDUSTRIAL SECTOR

The growth of the palm oil industry in Malaysia has been phenomenal over the last 30 years. From merely 400 hectares planted in 1920, the hectarage increased progressively to 54,000 hectares by 1960. By 1998, the oil palm planted area had increased tremendously to more than 3.0 million hectares - refer *Figure 1*. This dramatic increase in hectarage is a direct consequence of the Government's policy on crop diversification as well as intensification.

The accelerated growth in crop production resulted in a correspondingly rapid increase in palm oil production from 92,000 tonnes in 1960 to 8.3 million tonnes in 1998. Present projections indicate an increase of palm oil production to about 9.5 million tonnes by the end of 1999. Today, Malaysia is the world's largest producer and exporter of palm oil accounting for nearly 49.5% of world production and 64.5% of world exports - refer *Figures 2 and 3*. In addition, palm oil was also the largest traded commodity in the edible oil market in 1998, accounting for almost 22.4% of the oil and fats marketed worldwide.

This rapid growth in oil palm planting also saw a parallel growth in related manufacturing activities such as in the milling, refining and oleo-chemical sectors. Encouraged further by the government's incentives to exploit the country's rich agro-based resources, the refining of palm oil and palm kernel oil began to assume prominence in the1970's, and oleo-chemical industries in the 1980's.

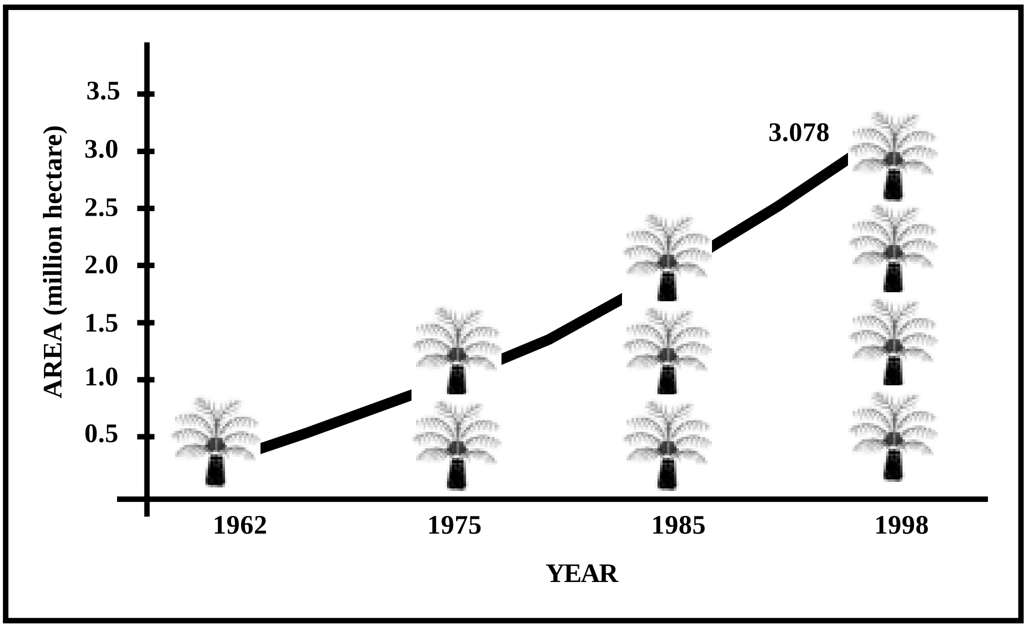


Figure 1: Malaysia: Cultivated Area Under Oil Palm

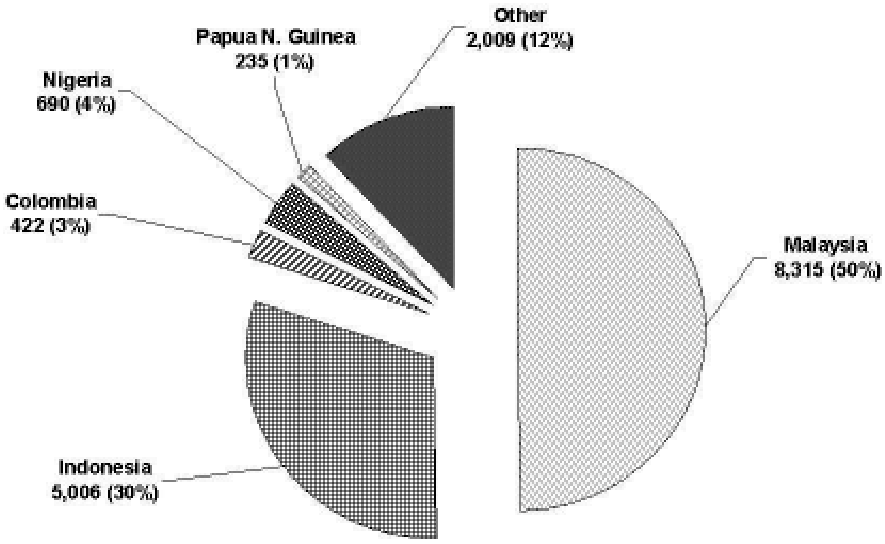


Figure 2 : World Exports of Palm Oil by Major Producing Countries - 1998 ('000 tonnes)

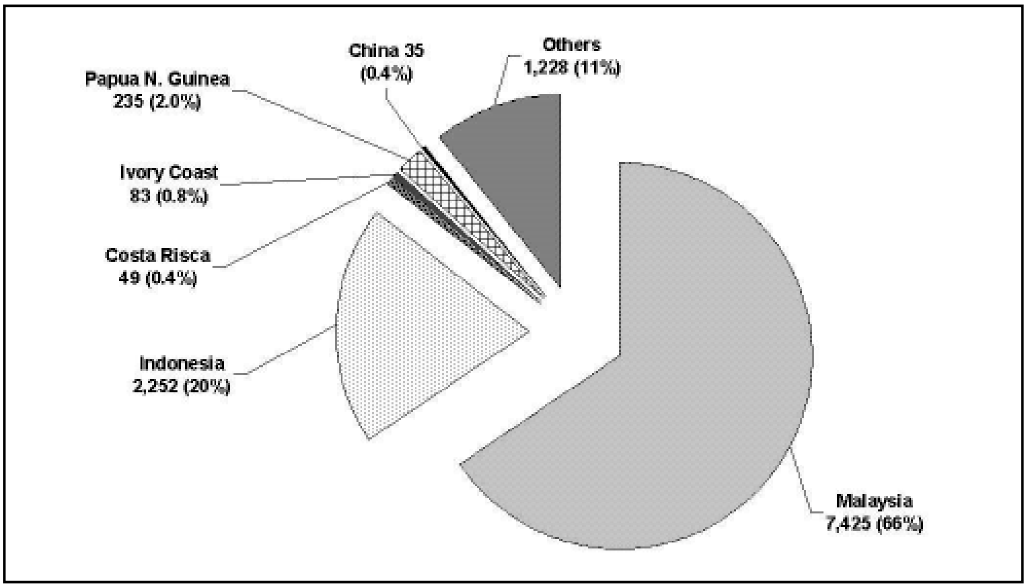


Figure 3 : World Production of Palm Oil by Major Producing Countries - 1998 ('000 tonnes)

2.3 POTENTIAL FOR ADVERSE ENVIRONMENTAL IMPACTS

On the upstream side, the potential for adverse environmental impacts of this rapid transformation of natural forests to mono-culture are primarily ecological. There are also the environmental implications and typical environmental problems associated with plantation agriculture *vis-à-vis* soil erosion and loss of soil fertility during land preparation, water pollution due to application of fertilisers and pesticides, and agricultural run-off, etc. However, it is in the downstream processing of the oil palm crop or fresh fruit bunch, i.e. extraction of crude palm oil, that this agro-industry was notable in the 60's and 70's for its adverse impact of extensive pollution of the country's surface waters.

A significantly large quantity of water is required in the palm oil extraction process. Palm oil mills are therefore typically located close to rivers and streams that provide them with the needed water supply. In addition, being a plantation-based industry, palm oils mills are primarily located within the estates that supply the oil palm fruit and these estates may stretch far into the interior of the country. As a result of the interior location of palm oil mills, the discharge of palm oil mill effluents have the potential to pollute the receiving waterways from all the way upstream. Thus, riverine communities and users of rivers and streams are very vulnerable to the adverse pollution impact of indiscriminate discharges of palm oil mill effluent (POME).

The raw or partially treated POME has an extremely high content of degradable organic matter which is contributed in part by the presence of unrecovered palm oil. The organic content of raw

POME, as measured by the Biochemical Oxygen Demand (BOD; 3-day, 30°C), typically averages about 25,000 mg/L; the oil content of the effluent may ordinarily exceed 6,000 mg/l. This highly polluting wastewater can therefore cause severe pollution of waterways due to oxygen-depletion and other related effects. The daily POME volume and the population-equivalent of the raw effluent BOD load discharged by an average-sized palm oil mill (30-Tonne FFB per Hour) are 600 m^3/day and 300,000 persons, respectively.

Palm oil mills use the palm fibre and shell as solid boiler fuel to co-generate needed steam and electricity. In the past, palm oil mills also typically employed an incinerator to burn the empty bunches and recover the residual potash for use as fertiliser in the plantation. Poor control of the air emissions from these facilities often caused localised problems of air pollution.

2.4 THE ADVENT OF COMPREHENSIVE ENVIRONMENTAL CONTROL

The environmental problems traditionally caused by the palm oil industry are essentially two-fold:

- Pollution of rivers and streams due to discharge of large quantities of extremely polluting wastewater due to high organic content; and
- Air pollution due to dark smoke and particulate emissions from the boilers and incinerators and odour from effluent treatment systems or land application of wastes.

Comprehensive environmental control of the crude palm oil industry commenced soon after the enactment of the Environmental Quality Act, 1974 (EQA) and the establishment of the Department of Environment in 1975. In order to regulate the discharge of effluent from the crude palm oil industry as well as to exercise other environmental controls, the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Order, 1977 and the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations, 1977 were promulgated under the EQA. These were the first sets of industry-specific subsidiary legislation to be promulgated under the EQA for industrial pollution control.

In order to ensure that the crude palm oil industry would not be stifled by unnecessarily prohibitive environmental costs, and to facilitate timely regulatory compliance by the industry, the formulation of the effluent standards and promulgation of regulations were both preceded by in-depth government-industry consultation and consensus through the following institutional arrangements:

- Establishment of a consultative and advisory body consisting of the Department of Environment (DOE), the Malaysian Oil Palm Growers Council (MOPGC), and the Palm Oil Research Institute of Malaysia (PORIM). The primary task of this body was to initiate

and monitor the progress of waste treatment research, establish appropriate technology-based effluent discharge standards, and recommend an acceptable implementation schedule; and

- Appointment of PORIM to undertake and coordinate research and development on effluent treatment technologies, and to formulate technology-based effluent discharge standards;

The above pro-active and consultative approach of the Government in augmenting environmental control of the palm oil and rubber industries is certainly the prime factor which has contributed to the improved environmental management of these economically important primary industries.

2.5 TREND TOWARDS BECOMING AN ENVIRONMENT-FRIENDLY INDUSTRY

The extremely rapid expansion of the palm oil sector during the 70's and 80's had the potential for widespread and severe environmental pollution impacts. Fortunately, this situation was abated as a result of timely intervention and the concerted action of the environmental authorities and industry alike. The palm oil industry, when properly managed, has the potential for turning into an exceptionally environment-friendly industrial sector.

A "zero waste" concept, that is now being pursued as an environmental goal for this agro-industrial sector, is expected to position this industrial sector as a model to be emulated. This Zero Waste Concept is centered on complete recycling and/or utilisation of all perceived waste components and by-products generated by the oil palm sector, from the plantation to the milling operations.

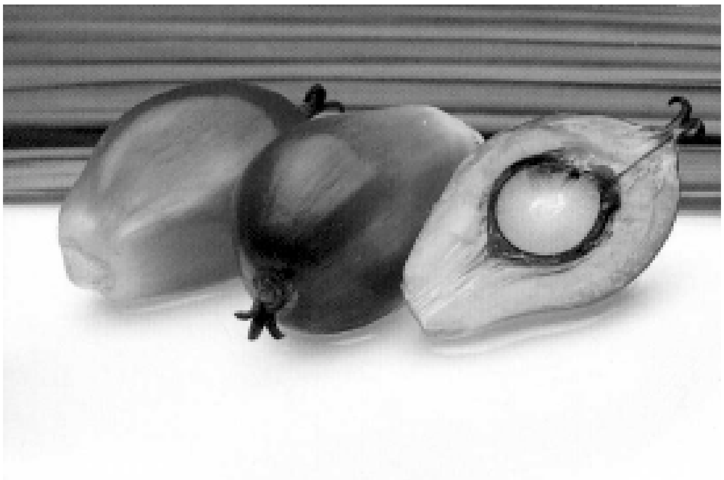
The transformation of oil palm from a wild to a domesticated tree crop, growing in neat rows under well-managed plantations, obviously incurred considerable cost. Much research was necessary to comprehend this 'new' crop and successfully adapt it to its new home. It was during this development that much was learnt about the crop and its impact on the environment.

The outstanding successes of oil palm plantation development in Malaysia also provided new opportunities and challenges such as in the downstream processing technology. This was once again a pioneering effort that demanded leadership as R&D in this field was very much lacking elsewhere in the world. Almost single-handedly, Malaysia was responsible for technological developments that are considered economically sound as well as reasonably sensitive to environmental needs.

Throughout its entire development in Malaysia, both upstream and downstream, the oil palm and its products have always been linked with the environment. It is this sensitivity to the environment that sees the crop to be what it is today.

2.6 PRODUCTION QUALITY AND ENVIRONMENTAL MANAGEMENT SYSTEM

The introduction of international standards on quality management, ISO 9000 and environmental management system, ISO 14000, have presented a positive driving force to encourage industry to self- improve, self-regulate and increase their market competitiveness. The crude palm oil industry should strive to accomplish certification under ISO 9000 and ISO 14000, within a reasonable time-frame, in order to enhance product quality while meeting the desired environmental performance objectives.



Oil Palm Fruits

Crude Palm Oil and Kernel Oil

3.0 THE EXTRACTION PROCESS FOR CRUDE PALM OIL AND SOURCES OF POLLUTION

3.1 INTRODUCTION

Palm oil mills in Malaysia process fresh fruit bunches (FFB) received from the oil palm plantations into crude palm oil (CPO) and other by-products. Two products are produced in a palm oil mill. They are crude palm oil (CPO) and palm kernel. Palm kernels are processed at palm kernel crushing plants into palm kernel oil. A few palm oil mills in Malaysia have also included in their operations the palm kernel crushing facilities.

3.2 EXTRACTION OF CRUDE PALM OIL (CPO)

A process flow diagram for the extraction of crude palm oil and a typical material balance sheet are presented in *Figures 4 and 5,* respectively. They are briefly described below.

3.2.1 Reception, Transfer and Storage of Fresh Fruit Bunches

Ripe fresh fruit bunches (FFB) are harvested in the oil palm plantations and transported as soon as possible to the palm oil mills for immediate processing.

A number of transportation systems are available. Lorries and tractors with tippers are the common ones. In some plantations with flat terrain, cages are sent by rail to the estates to transport the FFB to the palm oil mills. The FFB is normally unloaded onto a ramp and then to sterilizer cages.

Care must be taken in harvesting, handling and transportation of FFB so that the FFB is not damaged. The damaged palm fruits will give rise to poor quality crude palm oil (CPO) due to increased free fatty acid (FFA) content.

3.2.2 Sterilization

After loading into the sterilizer cages, the FFB is subjected to steam-heat treatment in horizontal sterilizers. Saturated steam at a pressure of 3 kg/cm^2 and a temperature of 140^oC is used as the heating medium. The FFB is usually steamed for 75 to 90 minutes.

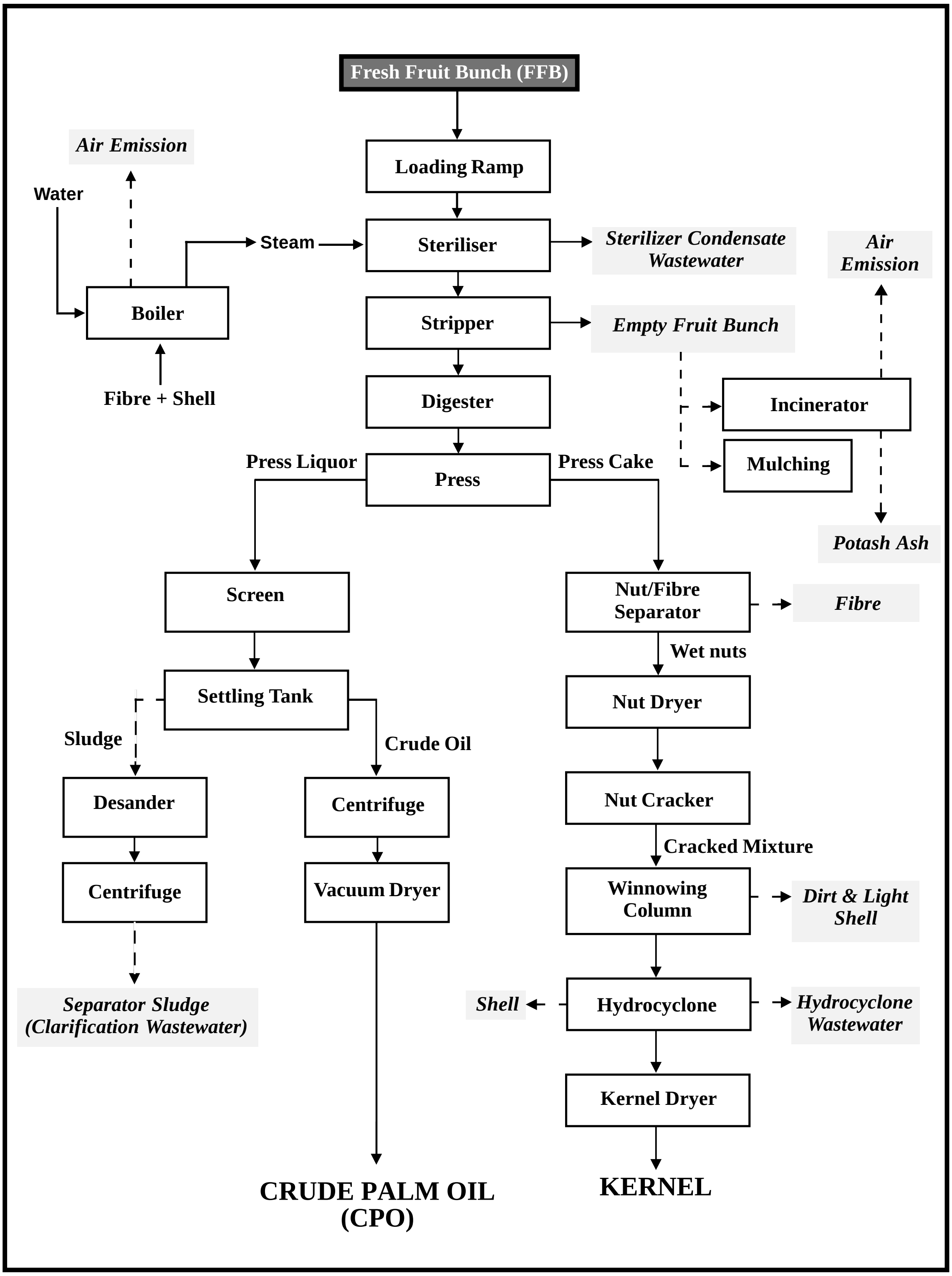


Figure 4 : Conventional Palm Oil Extraction Process and Sources of Waste Generation

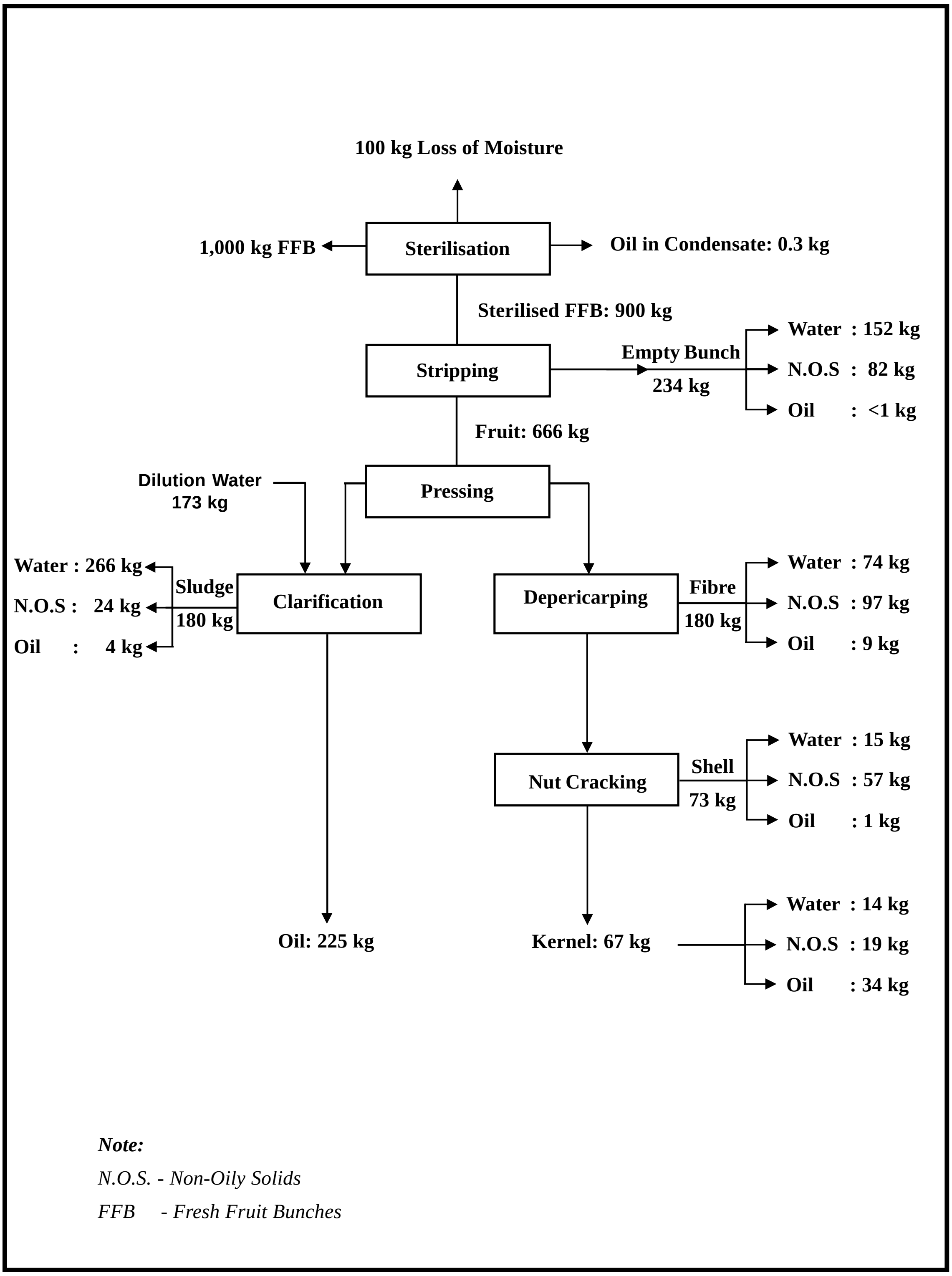
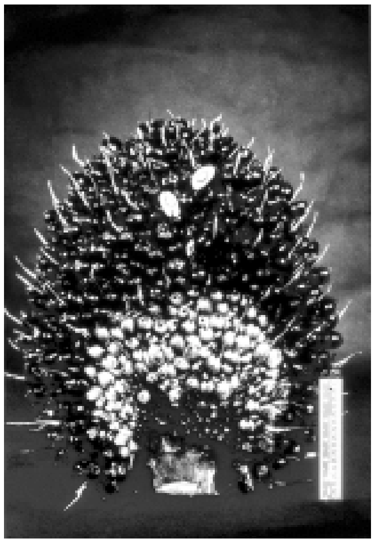


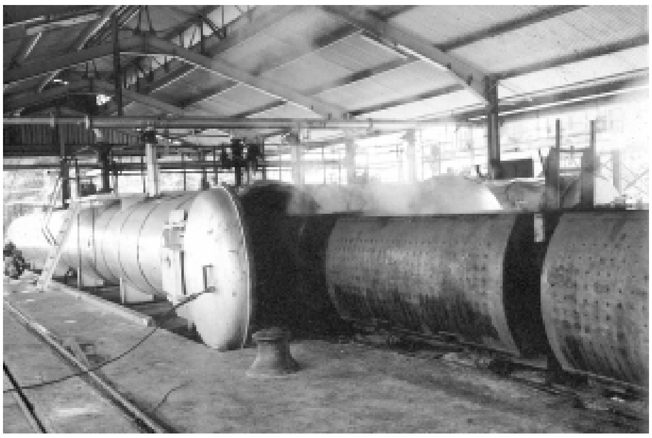
Figure 5 : Typical Mass Balance for Mill Processing of Palm Fruit

Harvesting Oil Palm Fruits

Loading and Transporting of Fresh Fruit Bunches



Fresh Fruit Bunches



Sterilisation of Fresh Fruit Bunches

Preparing for Stripping Process

The main objectives of sterilization are as follows:

- Prevent further formation of free fatty acids due to enzyme action;
- Facilitate stripping of the fruits from the spikelets;
- Prepare the fruit mesocarp for subsequent processing by coagulating the mucilaginous material which facilitates the breaking of the oil cells; and
- Pre-conditioning of the nuts to minimize kernel breakage during pressing and nut cracking.

The sterilization cycles, times and patterns vary from mill to mill. A three-peak sterilization pattern is normally used. This is because of the compactness of the FFB that was brought about by the weevil pollination introduced in the early 1980s. The steam condensate is discharged as wastewater and referred to as sterilizer condensate.

3.2.3 Stripping

After sterilisation, the FFB are fed to a rotary drum-stripper where the fruits are separated from the spikelets or bunch stalks. As the drum-stripper rotates, the bunches are lifted up and then dropped again repeatedly as the bunches travel along the stripper. The fruits are knocked off the bunch by this action. The detached fruits pass through the bar screen of the stripper and are collected below by a bucket conveyor before being discharged into the digester. The empty bunch stalks pass out at the end of the stripper continuously and are collected and handled separately.

3.2.4 Digestion

Digestion involves mashing of the palm fruits under steam heated conditions. Heatin can be either by steam jacket around the digester or by direct live steam injection. The digester consists of a vertically arranged cylindrical vessal fitted with a rotating shaft carrying a number of stirring arms. The fruits are mashed by the rotating arms. This mashing of the fruits under heating breaks the oil-bearing cells of the mesocarp. Thus, some palm oil is released and is collected in the crude oil tank together with the pressed oil described below. In order to have good digestion of the fruits, it is important to maintain the digester full all the time at about 90^{o}C.

3.2.5 Crude Palm Oil Extraction

Twin screw presses are generally used to press out the oil from the digested mash of fruits under high pressure. Hot water is added to enhance the flow of the oils. The crude oil slurry is fed to a clarification system for oil separation and purification. The fibre and nut (press cake) are conveyed to a depericarper for separation.

Ideally, the press should be operated at a high enough pressure to press out all the oil in the mesocarp without breaking any nuts. However, this can never be achieved in practice. Higher pressing pressure will obviously result in lower oil loss in the fibre but will cause higher nut breakage or vice versa. Therefore, this is more of a compromised operation.

It is undesirable to have high nut breakage as it will result in high broken kernel and subsequently higher kernel loss in the recovery process. Furthermore, the palm oil will be “contaminated” by the “kernel oil”.

It is possible to reduce the nut breakage by employing double pressing. This is being practiced by a number of palm oil mills in the country. As the name implies, it consists of two pressing operations. The first pressing presses the mashed fruits at a lower pressure. A practical set of operating conditions has to be obtained to reduce the nut breakage to an acceptable minimum. The fibre, after separating from the nut, is sent for second pressing at a higher pressure to recover the residual oil from the fibre.

3.2.6 Clarification and Purification of the Crude Palm Oil

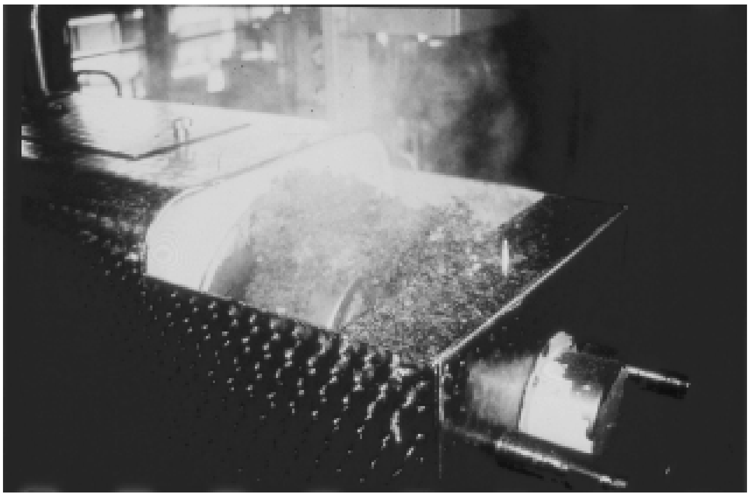
The crude palm oil (CPO) from the presses consists of a mixture of palm oil (35%-45%), water (45%-55%) and fibrous materials in varying proportions. It is pumped to a horizontal or vertical clarification tank for oil separation. The temperature of the clarification tank content is maintained at about 90^{o}C to enhance oil separation. The clarified oil is continuously skimmed-off from the top of the clarification tank. It is then passed through a high speed centrifuge and a vacuum dryer before it is sent to the storage tanks. The oil at this stage has a moisture and dirt content of below 0.1% and 0.01%, respectively.

The underflow from the clarification tank still contains some oil and this is recovered by passing the underflow through a sludge separator. The recovered oil is returned to the clarification tank.

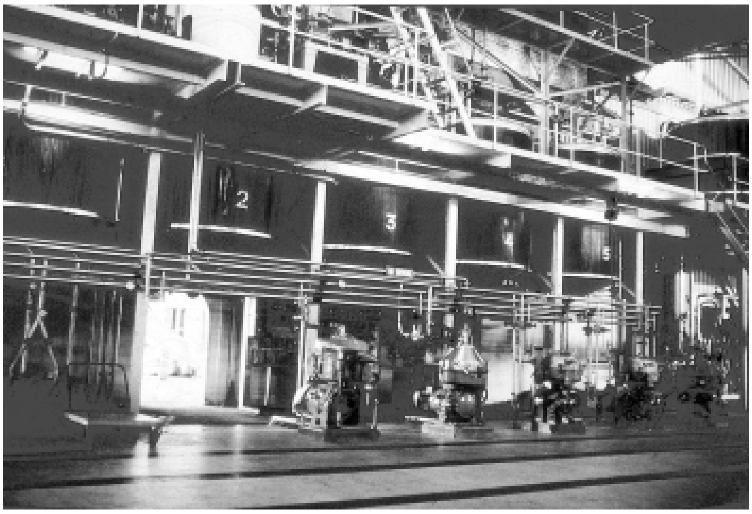
The other stream consisting of water and fibrous debris is discharged as wastewater, which is generally referred to as separator sludge or clarification wastewater.

3.2.7 Depericarping and Nut Fibre Separation

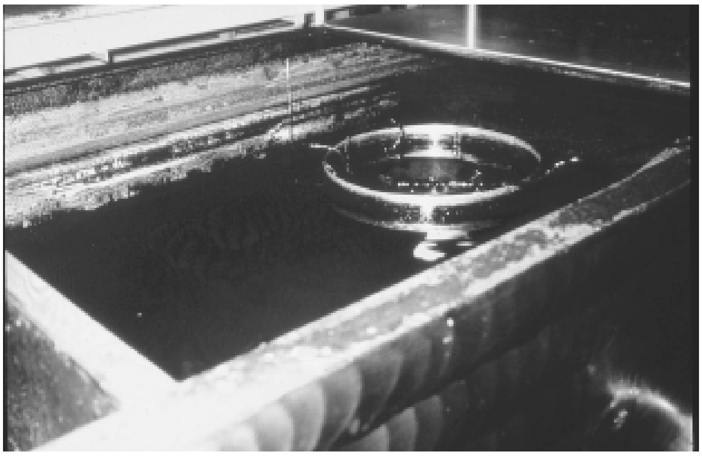
The press cake discharged from the screw press consists of moisture, oily fibre and nuts (including broken ones and kernels), and these are conveyed to a depericarper for nut and fibre separation. The conveyor is fitted with paddles which breakup the press cake on the way to the depericarper. The fibre and nuts are separated by a strong air current induced by a suction fan. The fibre is sent to the boiler house and is used as boiler fuel. The nuts are sent to a rotating drum where any remaining fibre is removed before they are sent to a nut cracker.



Twin Screw Presses are used to extract the oil after the Digestion Process



Clarification of Crude Palm Oil



Close-up View of a Clarification Tank

The air velocity has to be accurately determined for efficient nut and fibre separation. Conversely, if the air velocity is too low, blocking of the separation duct and cyclone can occur. Such occurrence will affect the throughput of the palm oil mill.

3.2.8 Nut Cracking

Nuts coming from the nut fibre separator are usually still warm, and a large number may have the kernels sticking to the shell. Cracking of the nut at this stage, by the conventional centrifugal-type nut-cracker, will result in the splitting of the nuts and any kernels sticking to the broken shell will be lost. Thus, cooling of the nuts to loosen the kernels before cracking will result in better cracking efficiency and kernel recovery. Moreover, warm nuts are more difficult to crack as the shells are more elastic.

However, with the introduction of the ripple mill for nut-cracking, drying of the nuts is no longer necessary, especially if the FFB have been effectively sterilized.

3.2.9 Separation of Kernels and Shells

The methods employed to separate the kernels and shells are based on the difference in specific gravity (SG) between the kernels and the shells. Undried kernels and shells have a SG of about 1.07 and 1.15-1.25, respectively. Thus, a separation medium consisting of clay suspension or salt solution with a SG of 1.12 will effectively separate the kernels and the shells. The choice of which depends on the availability, costs and maintenance of the materials and equipment.

Presently, the most popular separator is the hydrocyclone which is much easier to operate and maintain.

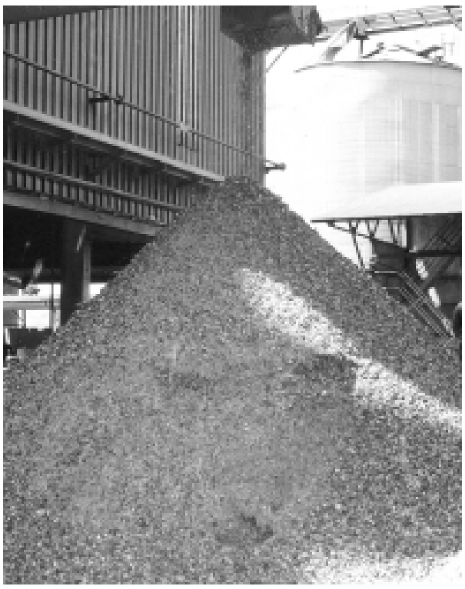
The discharge from this process constitutes the last source of wastewater stream, i.e. hydrocyclone wastewater.

3.2.10 Palm Kernel Drying

The palm kernels have to be dried to below 7% moisture in order to prevent the growth of mould and permit a longer storage time. The growth of mould on kernels not only spoils their appearance but also promotes the hydrolysis of the palm kernel oil. Palm kernels are commonly dried in a silo dryer. Drying is achieved by blowing a current of warm air through the kernels in the silo. In a large silo, it is important to avoid over-heating or over-drying in order to prevent the palm kernel oil from being pre-maturely "liberated".

The dried kernels are traditionally bagged for sale. As a recent practice, palm oil mills have built kernel bunkers and the kernels are transported in bulk instead of in bags. The kernels are normally sold to palm kernel crushers for palm kernel oil production.

Hydrocyclone is employed to separate the kernels and shells



Shell and fibre are used as boiler fuel

3.3 SOURCES OF WASTE GENERATION

The principal sources of liquid, gaseous, and solid waste generation in palm oil mills are identified in *Figure 4*. These are briefly described in the sections below.

3.3.1 Sources of Liquid Effluent

Large quantities of water are used during the extraction of crude palm oil from the fresh fruit bunch. About 50% of the water results in palm oil mill effluent (POME), the other 50% being lost as steam, mainly through sterilizer exhaust, piping leakages, as well as wash waters.

The POME comprises a combination of the wastewaters which are principally generated and discharged from the following major processing operations (refer *Figure 6*):

- Sterilization of FFB - sterilizer condensate is about 36% of total POME;
- Clarification of the extracted crude palm oil - clarification wastewater is about 60% of total POME; and
- Hydrocyclone separation of cracked mixture of kernel and shell - hydrocyclone wastewater is about 4% of total POME.

3.3.2 Sources of Gaseous Emission

There are two principal sources of air pollution in palm oil mills:

- Boilers that use the waste fibre and shell materials; and
- Incinerators that burn the empty fruit bunches(EFB) for recovery of potash ash.

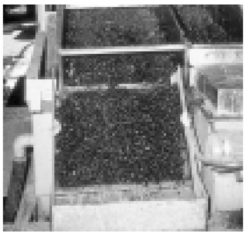
Smoke and dust emissions are the main concerns due to incomplete combustion of the solid waste materials. The characteristics of the emissions are presented in *Section 4*. Palm oil mills are generally self-sufficient in terms of energy requirements due to the availability of adequate quantities of the fibre and shell materials that are used as solid fuel in the steam boiler.

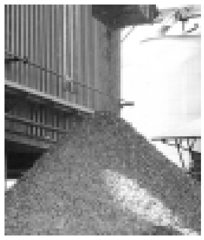
Typical Palm Oil Mill emitting Black Smoke

3.3.3 Sources of Solid Waste Materials and By-Products

As identified in *Figure 4***,** the solid waste materials and by-products generated in the palm oil extraction process are:

- Empty fruit bunches (EFB) - 23% of FFB;
- Potash ash - 0.5% of FFB;
- Palm kernel - 6% of FFB;
- Fibre - 13.5% of FFB; and
- Shell - 5.5% of FFB.





EFB **Kernel** **Fibre** **Shell**

As previously mentioned, the EFB may be incinerated to produce potash which is applied in the plantation as fertiliser, or applied in the plantation for fertiliser use by the superior process of mulching. The fibre and shell materials are used as boiler fuel. The palm kernel is sold to palm kernel oil producers who extract the palm kernel oil from the kernels.

The DOE has discouraged the use of incineration as a method of disposal of the empty fruit bunches in order to reduce air pollution. Today, empty bunches are laid in between the rows of oil palms and allowed to mulch and progressively release their nutrient elements to the soil. This method is, not only environmentally-friendly, but also advantageous in that it permits controlled release of the nutrients to the soil without significant loss due to rainfall and washout.

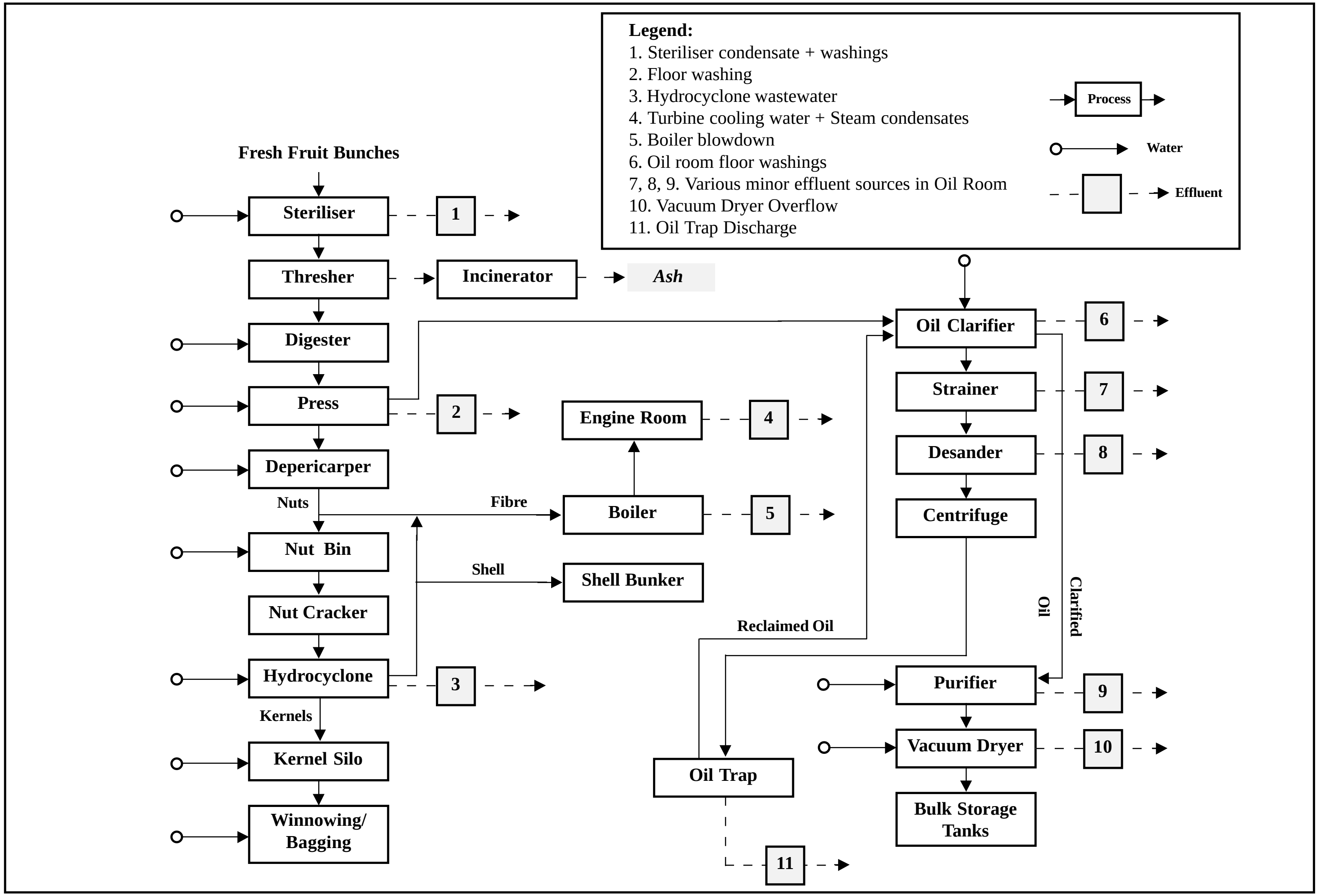


Figure 6: Sources of Effluent

4.0 ENVIRONMENTAL ISSUES

4.1 INTRODUCTION

Palm oil mills typically generate:

- Large quantities of oily effluent with extremely high organic content;
- Smoke and particulate air emissions ;
- Odour; and
- Noise

The environmental issues of the crude palm oil industry are primarily related to:

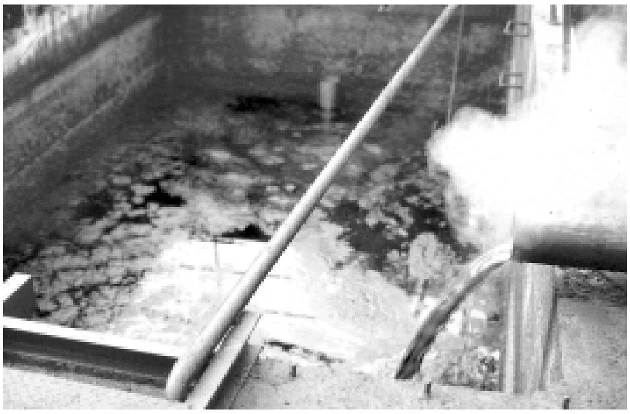
- Water pollution due to indiscriminate discharge of untreated or partially treated palm oil mill effluents into public watercourses;
- Improper interim storage of solid waste materials including boiler and incinerator ash, decanter solids, spent bleaching earth and sludge separator residue;
- Improper land-application techniques or practices for solid and/or liquid wastes;
- Air pollution due to the use of solid fuel fired boilers and incinerators for empty bunches;
- Odour emission from poorly managed effluent treatment systems, especially, if they are located in close proximity to neighbouring residential areas; and
- Some noise from the milling processes.

Palm oil mills are traditionally located near rivers from which water is abstracted for their milling operations. Prior to the advent of strict environmental control, some palm oil mills conveniently discharged their effluents into the rivers in an untreated or partially treated condition as this was the cheapest method of POME disposal. In the case of extremely large rivers with adequate waste assimilative capacities, some beneficial effects may have been initially derived due to available nutrients and enhanced growth of micro-plankton which are essential food for aquatic life, such as fish and prawn.

However, excessive quantities of untreated POME will deplete a waterbody of its oxygen and suffocate the aquatic life. Untreated POME from an average-sized palm oil mill, i.e. processing capacity of about 30-tonne FFB per hour, has an organic content equivalent to raw domestic sewage from a population of 300,000 persons. Thus, the impact of raw POME discharge to a relatively small river can be devastating to its eco-system and beneficial uses.

The smoke and other particulates in the air emissions from palm oil mills can be a serious source of public complaint when the mills are poorly located close to inhabitants and the emissions are unabated.

Noise is usually a much lesser external environmental concern; noise levels are ordinarily within acceptable limits at the palm oil mill perimeter fencing.



Palm Oil Mill Effluent (POME)

Air Emissions from Incinerators

Air Emissions from Boilers

4.2. QUANTITIES AND CHARACTERISTICS OF PALM OIL MILL EFFLUENT (POME)

4.2.1 Effluent Characteristics

Up to about 1.5 cubic meters of water are typically used to process one tonne of fresh fruit bunches (FFB). Of this quantity, about 50% results in palm oil mill effluent (POME) while the other 50% is lost as steam and boiler blowdown, as well as through piping leakages and wash waters for tankers, etc., that are not combined with the effluent stream which reaches the wastewater treatment system.

The POME is a combination of wastewaters that are generated and discharged from the following three(3) principal sources (refer *Figure 6*):

- Sterilizer condensate (about 36% of total POME);
- Clarification wastewater (about 60% of total POME); and
- Hydrocyclone wastewater (about 4% of total POME).

There are other minor sources of relatively clean wastewater that may be included in the combined mill effluent (POME) which is sent to the wastewater treatment plant. These include turbine cooling water and steam condensates, boiler blowdown, overflows from the vacuum dryers, some floor washings. The volume of the combined POME discharge depends to a large extent on the milling operations.

A well-managed palm oil mill with very good housekeeping practices will generate about 2.5 cubic meters of POME per tonne of CPO produced; in terms of FFB this amounts to about 0.5 cubic meters of POME per tonne of FFB processed. However, the national average is about 3.5 cubic meters of POME per tonne of CPO, or 0.7 cubic meters per tonne FFB. This shows that much water can be saved through good milling and housekeeping practices.

Typical quality characteristics of the individual wastewater streams from the three(3) principal sources of generation are presented in *Table 1*. The raw combined POME is a thick brownish liquid discharged at a temperature of between 80 ^{o}C and 90 ^{o}C. It is acidic with a pH typically between 4 to 5. The typical quality characteristics of the raw combined POME are presented in *Table 2*.

The quality characteristics and nutrient composition of POME varies with the type and degree of treatment. The typical nutrient compositions of POME after various types and/or stages of treatment are presented in *Table 3.*

Table 1: Characteristics of Individual Wastewater Streams

PARAMETER*	STERILISER CONDENSATE	OIL CLARIFICATION WASTEWATER	HYDROCYCLONE WASTEWATER
pH	5.0	4.5	-
Oil & Grease (O&G)	4,000	7,000	300
Biochemical Oxygen Demand (BOD; 3-day, 30°C)	23,000	29,000	5,000
Chemical Oxygen Demand	47,000	64,000	15,000
Suspended Solids (SS)	5,000	23,000	7,000
Dissolved Solids (DS)	34,000	22,000	100
Ammoniacal Nitrogen (AN)	20	40	-
Total Nitrogen (TN)	500	1,200	100

*Note: * All parameter's units in mg/l except pH*

Table 2 : Characteristics of Combined Palm Oil Mill Effluent (POME)

PARAMETER*				
GENERAL PARAMETERS			METALS & OTHER CONSTITUENTS	
	MEAN	RANGE		
pH	4.2	3.4 - 5.2	Phosphorous	180
Oil & Grease (O&G)	6,000	150 - 18, 000	Potassium	2,270
Biochemical Oxygen Demand (BOD; 3-day, 30°C)	25,000	10,000 - 44,000	Magnesium	615
Chemical Oxygen Demand	50,000	16,000 - 100,000	Calcium	440
Total Solids (TS)	40,500	11,500 - 79,000	Boron	7.6
Suspended Solids (SS)	18,000	5,000 - 54,000	Iron	47
Total Volatile Solids (TVS)	34,000	9,000 - 72,000	Manganese	2.0
Ammoniacal Nitrogen (AN)	35	4 - 80	Copper	0.9
Total Nitrogen (TN)	750	80 - 1,400	Zinc	2.3

*Note: * All parameter's units in mg/l except pH*

Table 3: Typical Nutrient Compositions of Raw and Treated POME

TYPE OF POME	BOD (mg/l)	N (mg/l)	P (mg/l)	K (mg/l)	Mg (mg/l)
Raw POME:	25,000	950	150	1,960	345
Anaerobically Digested POME:					
Stirred tank	1,300	900	120	1,800	300
Supernatant	450	450	70	1,200	280
Slurry	190	320	40	1,495	260
Bottom slurry	1,000-3,000	3,550	1,180	2,390	1,510
Aerobically Digested POME:					
Supernatant	100	50	12	2,300	540
Bottom slurry	150-300	1,495	460	2,380	1,000

4.2.2 Pollution Load and Effects of POME Discharge

The total palm oil production in 1998 was about 8.3 million tonnes, which averages about 28,000 cubic meters per day. Based on this quantity of daily crude palm oil production, the following pollution load statistics may be derived for the palm oil industry as a whole:

- Total quantity of effluent generated per day (@ 3.5 m^3 effluent/tonne oil) : 98,000 cubic meters;
- Total BOD_3 load of raw effluent generated per day (@ 25,000 mg/L) : 2,450 tonnes ;
- Population-equivalent of raw effluent BOD_3 load (@ 0.05 Kg BOD/Capita/Day) : 49,000,000 persons.

The above pollution statistics indicate that if the entire palm oil industry discharges raw effluent, then the total pollution load of the industry would be equivalent to that of a population of 49 million people discharging raw sewage into waste-receiving watercourses. This pollution load is nearly 2.5 times the domestic sewage pollution load generated by the present population of Malaysia.

The population-equivalent of the raw effluent discharged by a single, average-sized palm oil mill of 30-Tonne FFB/Hour processing capacity is 300,000 persons. Thus, the raw effluent discharged by an average-sized palm oil mill has the same polluting effect on the waste-receiving watercourse as a city of 300,000 people discharging untreated sewage. The population-equivalent of the mill's treated effluent BOD load (BOD concentration of 100 mg/L) is 1,200 persons.

POME when discharged untreated or partially treated into a river or stream undergoes natural decomposition during which the dissolved oxygen of the river or stream is rapidly depleted. The palm oil present in the effluent may float to the surface of the waterbody and form a wide-spread film which can effectively cut-off and prevent atmospheric oxygen from dissolving into its waters.

When the organic load of POME that is discharged to a waterbody far exceeds its waste-assimilative capacity, the available oxygen in the waterbody is rapidly consumed as a result of the natural biochemical processes that take place. The waterbody may become completely devoid of dissolved oxygen. This will lead to anaerobic conditions in which hydrogen sulphide and other malodorous gases are generated and released to the environment resulting in objectionable odours. Other damaging effects include the decline and eventual destruction of aquatic life and deterioration in the riverine eco-systems.

4.3 CHARACTERISTICS AND EFFECTS OF AIR EMISSIONS

4.3.1 Boiler Air Emissions

The use of solid boiler fuel comprising of the mill's by-product materials, mainly fibre and shell, to generate steam often leads to intermittent dark smoke emission with carry-over of soot and partially carbonised fibrous particulates. In the particular case of manual-feeding or poorly regulated mechanised-feeding of the fibre and shell, such air emissions are primarily due to incomplete combustion of the feed materials.

The incomplete combustion is attributable to:

- Lack of steady-state conditions in the boiler furnace due to intermittent and manual fuel-feed;
- Insufficient combustion air due to over-feeding;

- Formation of localised hot spots leading to high volatilisation of tarry products;
- Insufficient secondary air feed or induced air turbulence, for full combustion of volatiles and soot; and
- Inadequate furnace residence time due to high suction of induced draught fan.

In the particular case of palm oil mills located off-estates and/or in close proximity to residential areas, the boiler emissions, if inadequately controlled, can be a source of public nuisance and complaint.

4.3.2 Incinerator Air Emissions

In the recent past, the incinerators used for burning the empty fruit bunches were of a simple square or octagonal brick design equipped with an overhead conveyor feed system leading into an open grate. All such incinerators are designed with natural draught systems to enable slow combustion in the presence of excess air. The EFB feed rate to the incinerator is manually-controlled and this can be a cause for occasionally inadequate combustion and excessive particulate emissions.

The typical open-grate design arrangement of the commonly used empty bunch incinerator with resulting low gas emission velocities makes it difficult for installation of dust arrestors. Incinerators therefore generally emit high levels of white smoke, the appearance of which is due to high moisture content.

Control of particulate air emissions is best achieved through proper incinerator design and introduction of mechanised feeding of empty fruit bunches. The incineration of empty fruit bunches, as a method of disposal as well as recovery of utilisable potash ash, is currently being discouraged by the DOE in favour of mulching of the EFB within the plantation in order to eliminate this source of air pollution.

4.4 IMPROPER INTERIM STORAGE OF SOLID WASTES

The main concern with improper interim storage of solid waste materials, including boiler and incinerator ash, sludge separator residue, decanter solids within the factory premises is the ease of access of these materials to effluent and stormwater drainage systems, especially in open areas exposed to rain. These materials will significantly increase the cost of effluent treatment if they find access into the effluent drains.

4.5 IMPROPER LAND APPLICATION OF POME

In the late 70's and early 80's, certain plantation groups had attempted to exploit the fertiliser value of POME by applying the raw effluent onto oil palm cropland. It was felt that if pre-treated, POME may loose some of its fertiliser value, while the application of raw POME could also circumvent the pre-treatment costs involved. However, such land-application of raw POME was not successful due to nuisance conditions that were created; these included a large fly population in the disposal areas as well as odour problems.

In view of the problems associated with land-application of raw POME, the DOE discouraged such application, and instead imposed a guideline requirement for pre-treatment of POME to a BOD concentration of less than 5,000 mg/L prior to permitted land-application. Even with this pre-treatment requirement, the application of POME onto cropland can result in the following pollution problems, if improperly controlled:

- Groundwater contamination;
- Surface water pollution due to excessive application and run-off into watercourses;
- Washout into watercourses due to heavy rainfall;
- Odour and fly nuisances.

The methods of land-application of pre-treated POME commonly practised are presented and described in *Section 6 and 7*.

Land Application of POME

5.0 REGULATORY FRAMEWORK

5.1 INTRODUCTION

The Environmental Quality Act 1974 (EQA), together with its amendments (Act A636, A953 and A 1030), is the most comprehensive legislation in operation for the prevention, abatement, control of pollution and enhancement of the environment. The EQA is a Federal legislation and therefore enforced by a Federal agency, the Department of Environment (DOE), under the administration of the Director General of Environmental Quality. The EQA and industry-specific regulations made thereunder for the crude palm oil industry, i.e., the Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations, 1977, are the principal legislative instruments in operation for comprehensive and systematic environmental control of this industry. The relevant provisions of other subsidiary legislation under the EQA, which are not industry-specific, may also be applied directly to the primary palm oil industry as and when deemed appropriate. These are:

- The Environmental Quality (Clean Air) Regulations, 1978 - for control of air emissions; and
- The Environmental Quality (Scheduled Wastes) Regulations, 1989 - for control of the ultimate disposal of toxic and hazardous wastes.

There also exist other pieces of legislation administered by Federal, State and Local Government authorities which have certain provisions for environmental control that can be generally applied to the crude palm oil mills. The exercise of environmental control (if any) under such legislation is usually *ad-hoc* and non-industry-specific, and these are therefore not discussed in this Handbook.

5.2 ENVIRONMENTAL QUALITY ACT 1974 & AMENDMENTS

In brief, the Environmental Quality Act 1974:

- Came into force on April 15, 1975;
- Has since been amended 3 times: in 1985, 1996 and 1998, respectively,

  to increase its effectiveness;
- Has 22 pieces of subsidiary legislation: 13 sets of regulations; 1 set of rules and 8 sets of orders for the exercise of control over pollution sources, as at 1999.

The 1996 amendment of the EQA was particularly significant in that, among others, it:

- Increased the penalties for offences from RM 10,000 to RM 100,000;
- Empowered the DOE to inspect an offending site without a warrant; and
- Authorised the DOE to request for an environmental audit, if deemed necessary.

The major changes in the recent 1998 amendment were:

- Introduction of guidelines for activities exempted from the open-burning prohibition;
- The DOE can prosecute an alleged offender only after getting the approval of the Public Prosecutor; and
- Increase in the penalty for open-burning from RM 100,000 to RM 500,000.

5.3 REGULATORY CONTROL OF THE CRUDE PALM OIL INDUSTRY

The promulgation of environmental quality regulations under the EQA for industrial pollution control commenced during the latter half of the 70's. At that time, the crude palm oil industry was considered the single largest industrial source of organic pollution *vis-à-vis* among the major pollution sources by industry sectors. The raw natural rubber industry was second to the palm oil industry in terms of organic pollution load generated by individual categories of industry. It was therefore decided that environmental control of both these industries warranted a licensed approach that would enable intimate control of individual factories, as well as provide a mechanism for permitting variable effluent standards to be applied based on the demands of prevailing environmental circumstances. The environmental quality regulations for the crude palm oil industry were the first set of regulations promulgated under the EQA for control of industrial pollution sources.

5.3.1 Licensed Control as Prescribed Premises under Section 18 and 19 of the EQA

In recognising that individual palm oil mills have an extremely high potential to pollute waterways, the "*prescribed premises*" approach of *Section 18 of the EQA***,** which provides for licensed environmental control of individual factories, was deemed appropriate and chosen for exercising such control of the crude palm oil industry.

- Th**e** *Environmental Quality (Prescribed Premises) (Crude Palm Oil) Order 1977*, prescribed factories that process oil palm fruit or oil palm fresh fruit bunches into crude palm oil, whether as an intermediate or final product, as "*prescribed premises*", which shall require a licence under *Section 18 of the EQA* for the occupation or use of their respective premises;

- Environmental control of crude palm oil mills is exercised through the imposition of appropriate conditions of licence which may pertain, not only to acceptable conditions of effluent discharge, but also to other types of waste disposal including air emissions and disposal of scheduled waste. However, the control of air emissions and disposal of scheduled wastes are ordinarily exercised through direct application of their specific regulations;
- New palm oil mills that are to be constructed must first obtain the prior written permission of the Director General of Environment under *Section 19 of the EQA* before commencement of site-preparation or any other construction work;
- As a matter of procedure, the project proponent is also required to obtain environmental clearance for the proposed site of a new factory at the earliest planning stage to ensure its suitability and minimal environmental control cost.

5.3.2 Regulatory Control of Effluent Discharge

The following regulations were promulgated under the Environmental Quality Act 1974 for environmental control of palm oil mills:

- The *Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977,* promulgated under the enabling powers of *Section 51 of the EQA*, which are the governing regulations and contain the effluent discharge standards and other regulatory requirements to be imposed on individual palm oil mills through conditions of licence.
- The principal regulatory requirements and elements of regulatory control are:
  - Application for an annual licence using *Form 1,* and according to procedures in the *Environmental Quality (Licensing) Regulations 1977*;
  - Licence fees charges consisting of processing fee of RM 100.00 plus an effluent–related amount computed according to the rates and procedures in the *Third Schedule* of the *Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977*;
  - Compliance with the applicable effluent standards [*Second Schedule* of the *Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977*] and other acceptable conditions of effluent discharge imposed as conditions of the *Licence (Form 2* of the Licensing regulations);
  - The current effluent discharge standards ordinarily applicable to crude palm oil mills presented in *Table 4*; Current pollution control practices, including commonly applied effluent treatment technologies, and available cleaner production measures that enable compliance with the effluent discharge standards are presented in *Section 6* and *Section 7*, respectively.

- Reporting of effluent discharge information to the DOE on a quarterly basis in the format of the Quarterly Return Form in the *First Schedule* of the *Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations, 1977.*

Table 4 : Prevailing Effluent Discharge Standards for Crude Palm Oil Mills

PARAMETER		PARAMETER LIMITS FOR CRUDE PALM OIL MILLS (SECOND SCHEDULE)	REMARKS
Biochemical Oxygen Demand (BOD; 3-Day, 30°C)	mg/L	100	
Chemical Oxygen Demand (COD)	mg/L	*	
Total Solids	mg/L	*	
Suspended Solids	mg/L	400	
Oil and Grease	mg/L	50	
Ammoniacal Nitrogen	mg/L	150	Value of filtered sample
Total Nitrogen	mg/L	200	Value of filtered sample
pH	-	5-9	
Temperature	°C	45	

*Note: * No discharge standard after 1984.*

5.3.3 Regulatory Control of Air Emissions

The extraction process for crude palm oil is not inherently a significant source of air pollution. However, palm oil mills use solid fuel fired steam boilers that utilise the fibre and shell material as the fuel, and incinerators that burn the empty fruit bunches for recovery of potash; and these are significant sources of air emissions. These combustion facilities periodically emit excessive amounts of smoke that have the potential to cause localised problems of air pollution especially if the palm oil mill is located in close proximity to residential areas.

The following specific provisions of the Clean Air Regulations are also generally applicable to palm oil mills:

- Siting of new facilities adjacent to residential areas (Part II);
- Burning of waste (Part III);

- Dark smoke emission (Part IV); and
- Emission of air impurities (Part V).

Based on the relevance of specific parameters, the Air Emission Standard C for new facilities and Standard B for existing facilities in *Part V* of the Clean Air Regulations, are generally enforceable with respect to palm oil mills. These may be referred to in *Appendix 1*.

Regulation 32 of the Clean Air Regulations requires that the best practicable means approach be applied to prevent the emission of noxious and offensive substances such as those listed in *Appendix 2*.

5.3.4 Regulatory Control of Noise Emission

With the exception of regulations for the control of noise from motor vehicles, there are currently no DOE regulations that require the control of noise from other sources such as industrial, construction, commercial activities, etc.

DOE regulations for the control of noise from various sources and activities are still at the drafting stage. These regulations stipulate acceptable ambient noise levels at the receptor level for various situations to safeguard public health. The World Health Organisation (WHO) has also recommended various guideline limits for noise levels for the purpose of hearing protection and human well-being. Fortunately, noise is not a major issue in the crude palm oil industry. The ambient noise levels in a palm oil mills are usually well within the acceptable level of 85 dbA.

5.3.5 Regulatory Control of Disposal of Scheduled Wastes

The disposal of toxic and hazardous wastes, which are classified and regulated as scheduled wastes by the DOE, are governed by the following subsidiary legislation of the EQA:

- The Environmental Quality (Scheduled Wastes) Order, 1989; and
- The Environmental Quality (Scheduled Wastes) Regulations, 1989;

The various provisions of the Environmental Quality (Clean Air) Regulations, 1978 for the control of air emissions are directly applicable to the crude palm oil industry.

Among other things, the Scheduled Wastes Regulations require that the DOE shall be notified by the waste- generator regarding the generation and storage of any scheduled wastes. The crude palm oil industry ordinarily does not generate any scheduled wastes and this matter is therefore not an issue.

6.0 POLLUTION CONTROL PRACTICES

6.1 INTRODUCTION

In the 70's and 80's, the rapidly expanding crude palm oil industry had generated considerable public concern and was the focus of DOE attention due to its alarming water pollution impact. Both, the industry and the Palm Oil Research Institute of Malaysia directed urgent research attention to end-of-pipe effluent treatment technologies in response to government requirements for pollution abatement. During this period, tremendous progress was achieved through the indigenous research effort on the treatment and utilisation of POME. In the present decade of the 90's, the focus of attention has shifted to in-plant process improvements *vis-a-vis* cleaner production technologies involving waste minimisation, and by-product recovery and utilisation.

This Section presents the pollution control practices of the crude palm oil industry with particular focus on end-of-pipe solutions; the in-plant measures are only briefly identified in this Section and described in more detail in *Section 7* on Pollution Prevention and the Cleaner Production Approach.

6.2 IN-PLANT CONTROL AND HOUSEKEEPING MEASURES

Effective in-plant process control and good housekeeping measures are most essential to minimise waste generation and wastage of resources, as well as to reduce the pollutant load to be removed in the effluent treatment process and its treatment costs. The following are the principal in-plant control and cleaner production measures for crude palm oil mills:

- Control of water usage;
- Control of oil clarification temperature;
- Control of oil spillages and leaks;
- Proper design and operation of oil traps;
- Separation of effluent and stormwater drainage systems; and
- Proper interim storage of solid waste materials.

Each of these measures is described in *Section 7* on pollution prevention and cleaner production technologies for palm oil mills. This Section will focus on the end-of-pipe treatment technologies of the crude palm oil industry.

6.3 TREATMENT TECHNOLOGIES FOR PALM OIL MILL EFFLUENT

6.3.1 Pre-Treatment of POME

The contents of POME are essentially organic and moderately biodegradable. The biodegradability is influenced by the extent of cellulosic materials present such as the palm fibre residues as well as the residual oil content. The effluent treatment technologies for POME are therefore invariably combinations of physical and biological processes. The physical treatment includes pre-treatment steps such as screening, sedimentation and oil removal in oil traps prior to the secondary treatment in biological treatment systems.

Sand and grit that accompany the fresh fruit bunch and residual oil are removed in a sand trap and/or oil trap. The oil trap consists of a baffled pit or sump that retains the wastewater for at least 10 hours. Hydraulic retention times (HRTs) of about 1 to 2 days are preferable for more effective oil removal and minimal loss of oil to the effluent.

Steam is sometimes used to heat oil-bearing wastewaters in the oil trap to improve oil separation and release. The oil that floats to the wastewater surface is manually skimmed-off and recovered on a regular basis and stored in drums. The skimmed oil is either sent to the clarifiers for further processing, or sold to soap manufacturers as raw material. The sand, grit and other settled solids are disposed-off onto the plantation land.

6.3.2 Biological Treatment of POME

The organic content of POME is generally biodegradable and treatment is based on anaerobic, aerobic and facultative processes. The processes are essentially biochemical and rely on the enhanced growth and metabolic activities of suitable microorganisms to breakdown the organic matter into simple end-products gases such as methane, carbon dioxide and hydrogen sulphide, and water.

The microorganisms involved are primarily bacteria and algae which result in the production of excess biomass (microbial cells) that needs to be disposed-off in the form of sludge. This sludge can be appropriately land-applied in the oil palm plantation as soil conditioner. A large number of biological treatment processes have been researched specifically for palm oil mill effluent in attempts to arrive at the most cost-effective treatment systems. These include:

- Anaerobic processes such as the anaerobic lagoon, conventional anaerobic digester, anaerobic contact process, and up-flow anaerobic sludge-blanket (UASB) reactor; and
- Aerobic (and facultative) processes such as the extended aeration system, aerated lagoon, and aerobic stabilization lagoons.

The available effluent treatment technologies for POMEs are based on a combination of the biological treatment processes and treatment units enlisted above. The biological treatment systems commonly employed are as follows:

- Anaerobic-cum-Facultative Lagoon System
- Anaerobic-cum-Aerated Lagoon System
- Anaerobic Reactor-cum-Aerated Lagoon System
- Anaerobic Lagoon-cum-Land Application System
- Anaerobic Reactor-cum-Land Application System

A Typcial Aeration System

A Typcial Lagoon System

(a) Anaerobic-cum-Facultative Lagoon System

The “ponding” system, which essentially consists of a combination of anaerobic, aerobic and/or facultative ponds or lagoons, is the most commonly used by Malaysian palm oil mills, about 85%. In this system, the anaerobic treatment process takes place in anaerobic ponds or lagoons. A schematic representation and the principal design features of a typical anaerobic-cum-facultative lagoon system, based the original design by one of the major plantation groups, is presented in *Figure 7*.

The essential components of the system are:

- De-oiling Tank;
- Acidification ponds;
- Methanogenic ponds;
- Facultative ponds; and
- Sand beds.

The essential process components and basic design features of the anaerobic-cum-facultative lagoon system (based on original ponding system configuration of the Boustead Plantation Group) are:

- De-oiling tank of concrete construction and hydraulic retention time(HRT) of 1.5 days for oil recovery, equalisation and cooling of the effluent;
- Two-phase anaerobic treatment in lagoons - an Acidification Phase and a Methanogenic Phase;
- The Acidification Phase of the anaerobic process takes place in two(2) ponds in series, each with a hydraulic retention time of 2 days. Acid-forming anaerobic bacteria or acidogens convert the hydrolysed complex organics into free fatty acids;
- The Methanogenic Phase of the anaerobic process takes place in two ponds in series - a primary anaerobic pond of 30-day HRT and an anaerobic maturation pond of 15-day HRT in which methane-forming bacteria or methanogens convert the free fatty acids into methane, carbon dioxide and other minor gases, and water;
- The anaerobic ponds are typically 5 to 7 meters deep to prevent or minimise introduction of oxygen through photosynthetic activity and/or atmospheric penetration;
- The anaerobically-treated effluent is then treated aerobically in a parallel-series system of four(4) facultative ponds having a combined HRT of 8 days;

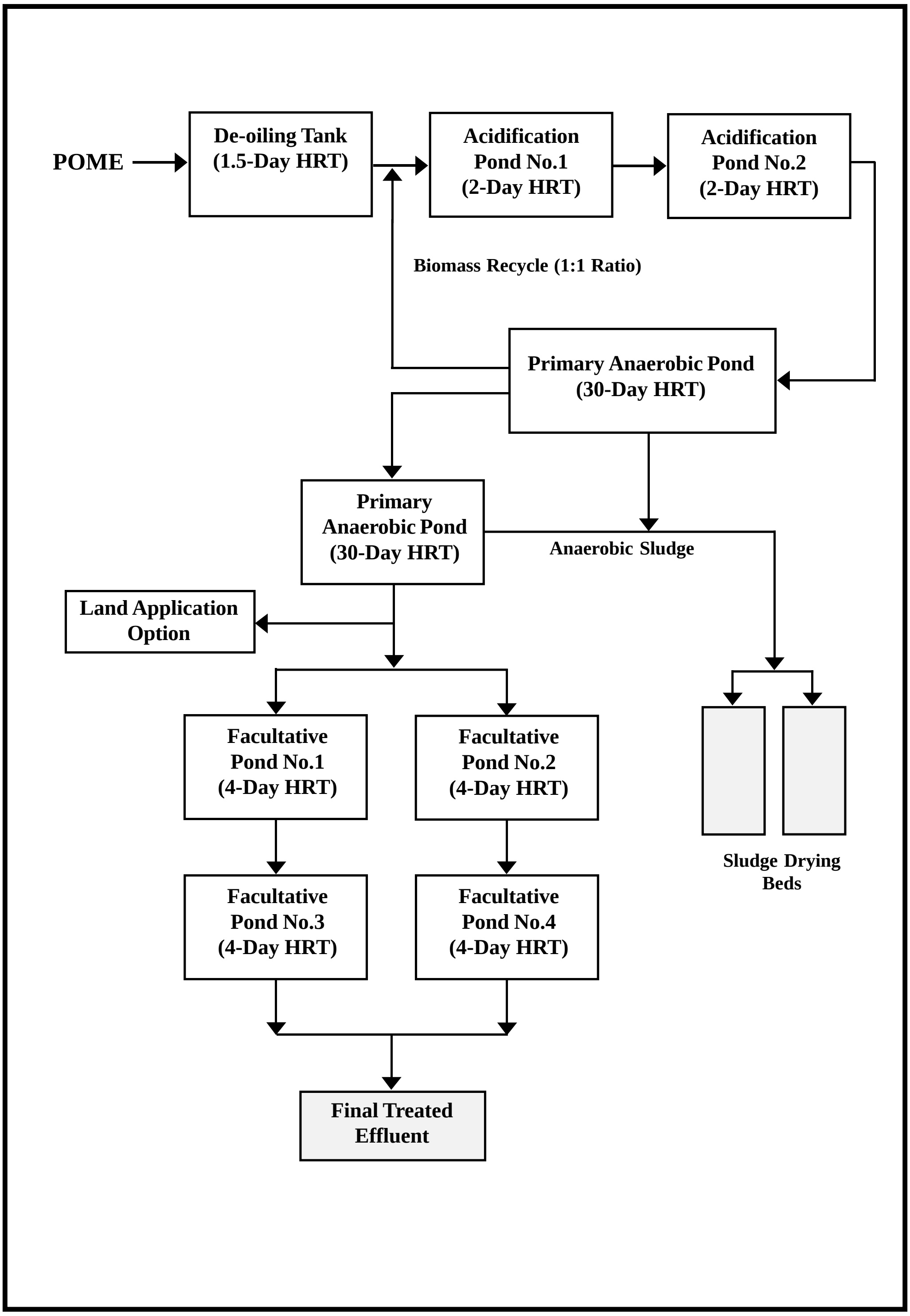


Figure 7: Anaerobic-cum-Facultative Lagoon System (Bi-phasic)

- The facultative ponds are relatively shallow with depths of between 1 and 1.5 meters to enable sunlight penetration and algal photosynthesis which is the source of the oxygen needed by the aerobic microorganisms;
- Sludge accumulated at the bottom of the ponds is periodically pumped using submersible slurry pumps onto the sand-drying beds; the dewatered sludge is applied on the oil palm plantation as soil conditioner;
- The overall treatment efficiency of this type of treatment system is about 99.5%, but extensive land areas are required.

The effluent from the anaerobic lagoon(s) is stabilised in the facultative lagoon(s) by biochemical oxidation of organic matter using air from natural atmospheric aeration as well as oxygen from algal photosynthesis. In the facultative lagoon, the bacteria and algae co-exist symbiotically. The bacteria decompose organic matter utilising oxygen in the process and generating carbon dioxide. During photosynthesis, the algae utilise the carbon dioxide and produce oxygen. The dominant group of algae is the chlorella group.

A well-designed and operated anaerobic-cum-facultative lagoon system is able to treat POME to meet the prevailing DOE effluent standards for crude palm oil mills presented in *Table 3* of *Section 5*.

The energy requirement of the anaerobic-facultative lagoon system is minimal if gravity flow is exploited throughout. Limited pumping is needed mainly for the periodic transfer of sludge form the ponds to the sludge beds and the energy requirement may be as low as 20 kW. A part-time attendant is sufficient to maintain the treatment system.

(b) Anaerobic-cum-Aerated Lagoon System

This treatment system is similar to the Anaerobic-cum-Facultative Lagoon System, except that the facultative lagoons are replaced with mechanically-aerated lagoons in which the oxygen for the aerobic biological processes are mechanically supplied. However, the first-stage treatment also uses the anaerobic lagoon process, but the number of lagoons and the basic design configurations may differ.

Facultative ponds are designed to be shallow for sunlight penetration and natural oxygen-supply through algal photosynthesis, and therefore occupy extensive land area. The use of mechanical surface aerators or diffused air aeration systems to supply oxygen in the case of aerated lagoons, enables the use of deeper lagoons which occupy much less land space. This type of treatment system also produces a more consistent treated effluent quality.

Lagoon depths of up to 5 meters can be applied, while the hydraulic retention time is usually between 15 and 20 days; i. e. extended aeration.

The treatment efficiency of mechanically-aerated lagoons is also generally higher; the overall treatment efficiency of the anaerobic-cum-aerated lagoon system can exceed 99.8%; final BOD_3 concentrations of less than 100 mg/L are consistently achievable. The operating costs are high due to the energy consumption of the mechanical aeration equipment and added maintenance requirements.

(c) Anaerobic Reactor-cum-Aerated Lagoon System

This system combines the anaerobic process with the aerated lagoon. However, the anaerobic process takes place in a tank digester instead of anaerobic lagoons. The anaerobic reactor processes have in the past found limited application in the palm oil industry due to the high material and construction costs, whereas available cheap plantation land and lower construction costs greatly favour the land-intensive anaerobic lagoon systems.

Tank digesters may have an open top or closed top for the purpose of increased treatment efficiency as well as to enable biogas recovery. In the closed-type, the biogas generated can be utilised as a source of energy.

The principal types of anaerobic reactor processes are briefly described below.

- **Conventional Anaerobic Digester:**

  The conventional anaerobic digester is essentially a continuous stirred-tank reactor (CSTR) with no solids recycle, i.e. the mean cell residence time (MCRT) of the system equals the hydraulic retention time (HRT). This type of anaerobic reactor requires a longer HRT to prevent washout of microorganisms and to achieve desired treatment efficiency. Mixing of the digester contents is performed using mechanical stirrers, or alternatively by gas-recirculation mixing in which the biogas is recycled through an emitter and draught tube (refer *Figure 8*). The longer HRTs of up to 20 days required for this type of anaerobic digestion process for POME significantly increase the cost of the system.

- **Anaerobic Contact Process:**

  The anaerobic contact process is the anaerobic equivalent of the activated sludge process. In the anaerobic contact process, the raw wastewaters are mixed with recycled sludge solids and then digested in a continuously-stirred digester tank (CSTR). The anaerobic contact reactor includes a settling tank for biological solids separation and recycle.

Gas formation in the digester tank (CSTR) normally continues to occur in the settling tank, and this tends to inhibit effective settling of the biomass to enhanced buoyancy of the suspended solids. This can be a major limitation of the process. Design modifications are needed to overcome the problem such as degasification and flocculated settling. This process has been used successfully for the stabilization of high-strength soluble wastes.

- **Up-flow Anaerobic Sludge Blanket (UASB) Reactor:**

  The UASB reactor system is based on upward flow of wastewater through a suspended layer or sludge blanket of active biomass. The wastewater, which enters at the bottom of the reactor, flows upward through the sludge blanket and during contact with the biomass biochemical conversion of the organic matter to methane and carbon dioxide gas occurs. After passing through the sludge blanket, the supernatant liquor and biogas enter a three-phase gas-solid-liquid separator. The biogas is separated in an inverted cone, while the liquor solids are allowed to settle in the settling zone. The treated wastewater is discharged via an overflow weir.

  Reported data indicate very favourable performance of UASB reactors. Design loading rates range between 8 and 17 kg COD/m^3.day with COD removal efficiency of up to about 90%.

A typical Anaerobic Reactor-cum-Aerated Lagoon System, which uses the open-top and completely-mixed anaerobic tank digester, is shown schematically in *Figure 9*.

Anaerobic tank digesters are much more capital intensive than anaerobic lagoons, but have the following advantages:

- Extremely compact and occupy a fraction of the space required by anaerobic lagoons;
- Higher organic loading rates and therefore much shorter hydraulic retention times;
- HRTs are about 10 to 20 days for closed tank digesters compared to about 45 to 80 days for anaerobic lagoons;
- Closed tank digesters with complete internal mixing and operating at the high thermophilic temperature range of between 42 ^{o}C and 55 ^{o}C require an HRT of about 10 days or less;
- The organic loading rate for closed-tank anaerobic digesters is typically about 3.0 to 5.0 Kg BOD_3/m^3.day;
- Open tank digesters without internal mixing and operating at the normal mesophilic temperature range of about 30 ^{o}C to 35 ^{o}C require an HRT of about 20 days;
- The organic loading rate for open tank anaerobic digesters is typically about 0.8 to 1.0 Kg BOD_3/m^3.day;

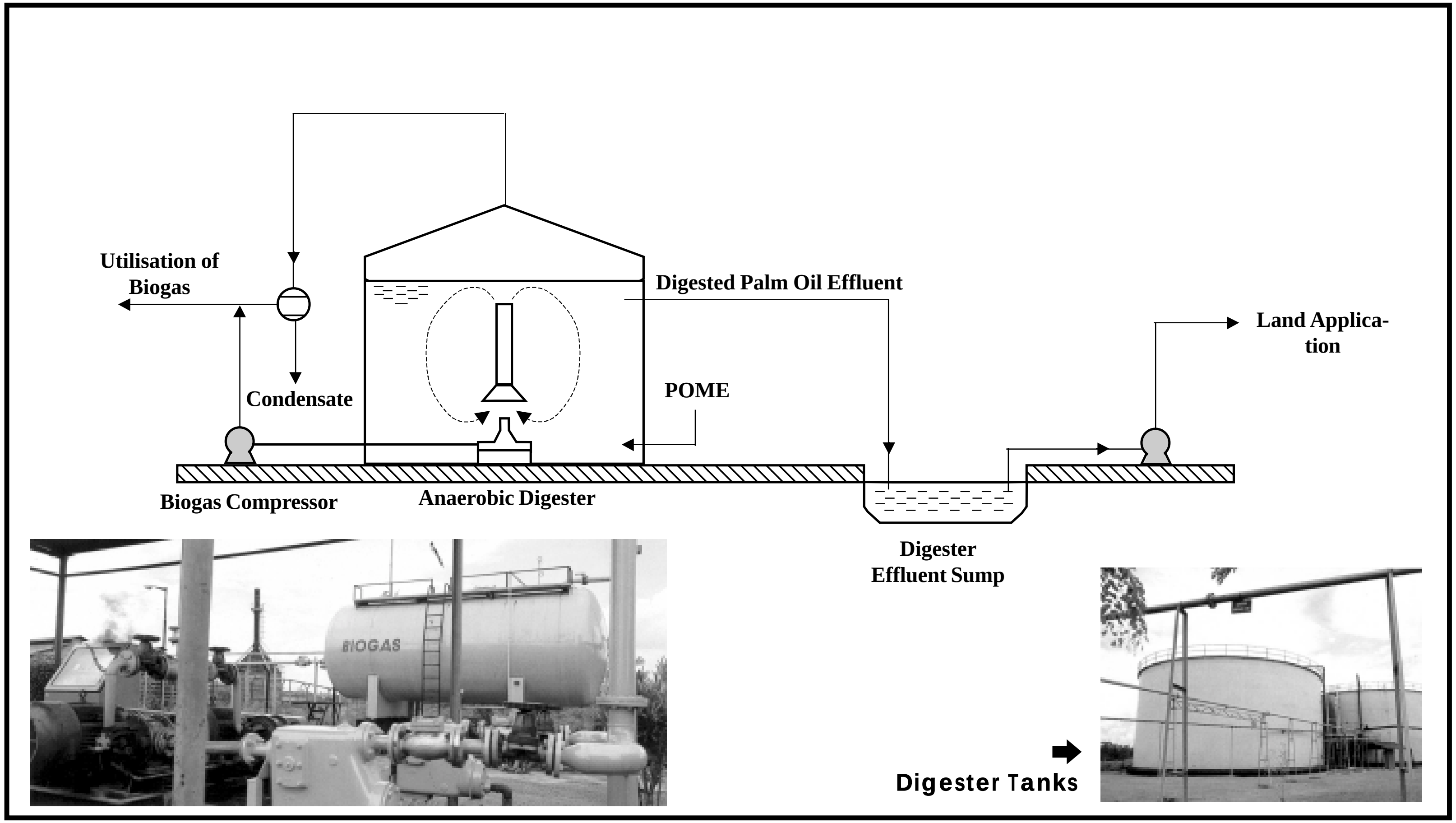


Figure 8 : Anaerobic Digester with Gas-Recirculation Mixing

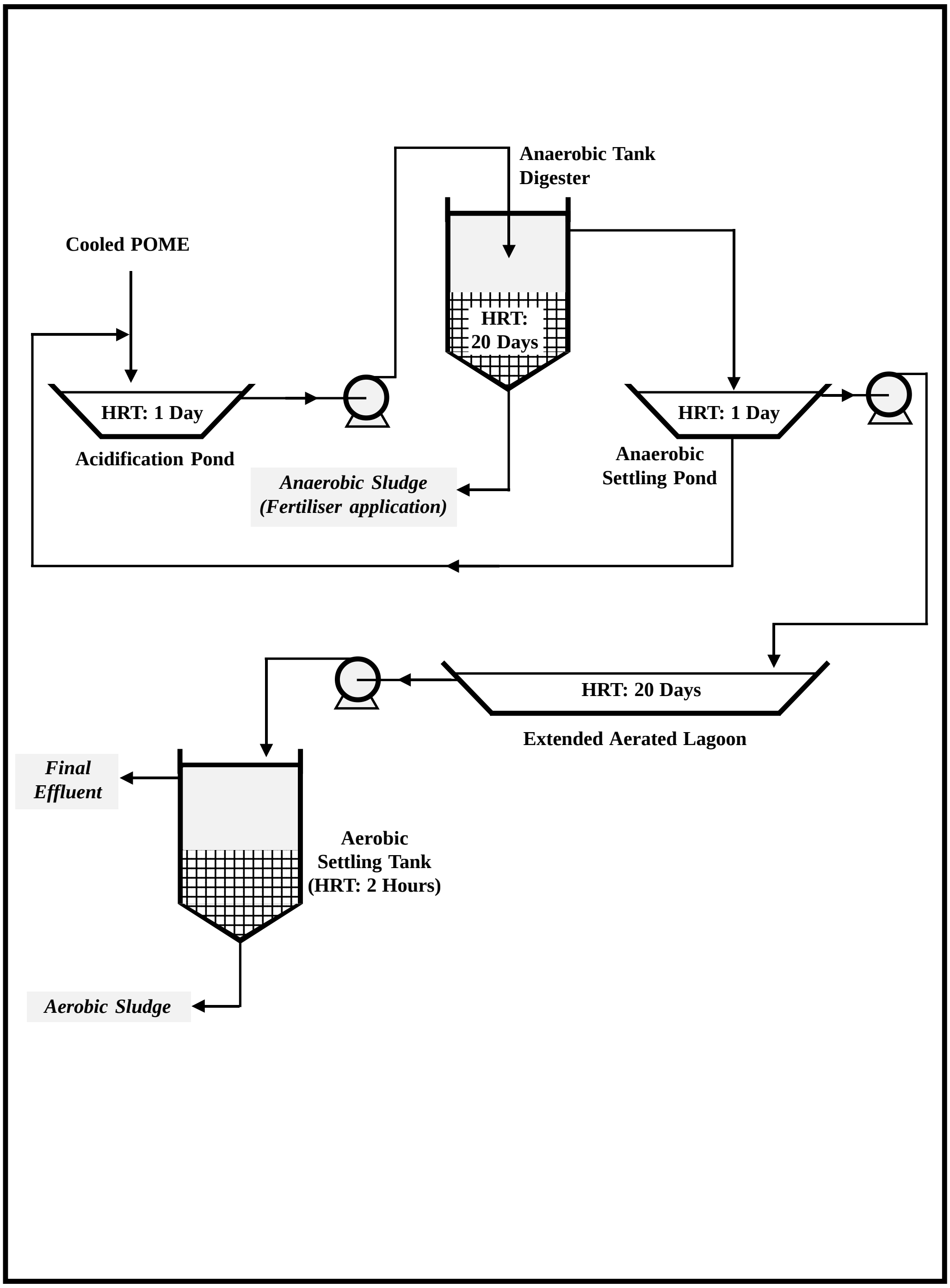


Figure 9: Typical Anaerobic Reactor-cum-Aerated Lagoon System

- Higher treatment efficiency of between 60% and 90% BOD removal;
- Biogas generated can be recovered and utilised as energy source.

Results of pilot studies on the treatment performance of a Thermophilic Anaerobic Contact Process are presented in *Table 5*. The overall treatment efficiency of the Anaerobic Reactor-cum-Aerated Lagoon System exceeds 99.8% and can produce a treated effluent that consistently meets the DOE prevailing BOD_3 standard of 100 mg/L.

Table 5: Performance of Thermophilic Anaerobic Contact Process

PARAMETER\TEMPERATURE	45°C	50°C	55°C	60°C+
BOD Loading, $kg/m^3.d$	3.1*	3.4*	3.3	3.0
BOD Removal, $kg/m^3.d$	2.9	3.2	2.9	2.9
Gas Production, m^3/d	28.8	36.0	47.0	42.5
Gas Yield, m^3/kg BOD added	0.9	1.1	1.4	1.4
Methane, %	60	65	64	69
Hydraulic Retention Time, Days	6	5	6	7
BOD Removal Efficiency, %	92.6	93.3	89.9	96.0

*Note: * Maximum BOD load achievable.*

6.3.3 Land Application Systems for Anaerobically-Treated POME

The palm oil industry generates a large quantity of effluent, usually about 0.5 to 1.0 cubic meter per tonne FFB processed, and contains high concentrations of plant nutrients (refer *Table 1 - Section 4*). The application of the anaerobically-digested effluent to appropriate cropland, not only provides nutrients and water to the vegetation, but is also a means of ultimate disposal of the effluent. As the effluent percolates through the soil the organic matter is reduced substantially by filtration, adsorption and biological degradation.

The anaerobically digested POME is utilised by some plantation owners as a source of inorganic fertiliser. The treated effluent, with a BOD of less than 5,000 mg/L to meet DOE requirements, is applied to cropland at rates corresponding to the nitrogen requirement of the particular crop. In the case of anaerobic digestion in tanks, the anaerobic effluent is collected in a pump sump or storage pond for removal of settleable solids and equalisation prior to land application. This is necessary to prevent blockage of the pumps and effluent distribution pipes by the solids present, as well as to create a uniform concentration of nutrients prior to cropland application.

The effluent is pumped to distribution tanks and then applied directly onto the cropland by gravity-flow or by pumping onto a system of inter-row flatbeds, long-beds or furrows. The available methods of land-application of effluent are briefly described below. The choice of the method of application for any plantation depends on several factors, such as soil-type, climatic conditions and the terrain of the area.

(a) Flatbed and Long-Bed Systems

The flatbed system consists of a series of shallow bunded-beds of about 15 centimeter depth. They are constructed along alternate inter-rows and usually occupy about one third of the inter-row space between oil palm trees. These flatbeds are inter-connected by channels. The anaerobically-digested POME is allowed to flow by gravity, or otherwise pumped to the top-most bed and then flows by gravity from bed-to-bed. When the lowest bed is filled up, the channel is closed and the effluent is directed to the next row of beds. This is continued until all the beds are filled. In flat terrain, the long-bed system is adopted in which the construction is similar to the flatbed, except that each bed may be as much as 70 meters in length.

(b) Spray-Line-Sprinkler Irrigation System

The anaerobically-digested POME is applied by means of a fixed or movable spray-line sprinkler system. This system consists of a network of pipes with attached sprinkler heads spaced at regular intervals within the cropland. The fixed network system covers the entire cropland with a system of manually operated valves that are used to distribute the effluent to selected segments of the cropland on a rotation basis. The movable spray-line is more economical as it need not cover the entire cropland, and consists of a detachable network of pipes and valves and a set of detachable sprinkler heads that can be moved, installed and used segment by segment of the cropland.

Spray-Line-Sprinkler System

(c) Tractor-Tanker Spraying System

The equipment required for this system is a tractor-tanker and centrifugal pump. The anaerobically-digested POME is transported to the field in a tractor-drawn tanker. The effluent is applied onto the cropland by spray-pumping with the assistance of a centrifugal pump mounted on the tanker chassis.

6.3.4 Potential Zero Waste Evaporation Technology for POME

Environmental regulations for the palm oil industry have undergone vast changes over the past decade. The Department of Environment has imposed increasingly stringent standards for POME discharge into watercourses, especially for new palm oil mills. In some pollution-sensitive areas, palm oil mills are not allowed to discharge effluent with a BOD_3 exceeding 20 mg/l, while in certain strategic areas requiring stringent pollution prevention a zero-discharge requirement has been imposed.

Most POME treatment plants have been constructed to meet a BOD_3 concentration limit of 100 mg/l. This effluent BOD_3 limit is ordinarily achievable if the treatment systems are well-designed and operated. Nevertheless, it is observed that not all palm oil mills comply with the discharge standard consistently or at all the times. Therefore, there may be a need to review the waste management strategies for palm oil mills.

Present trends in industrial waste management are towards waste minimization at source and/or recycling of wastes. Over the last 10 years, the paradigm of management of palm oil mill wastes has shifted from "*treatment and disposal*" to "*beneficial utilization of an asset*". POME contains substantial quantities of valuable plant nutrients (refer *Table 1 - Section 5*) and is used as a fertilizer substitute. Land-application of POME has become a standard practice for those mills with oil palm plantations or other suitable cropland nearby. This has resulted in substantial savings in fertilizer costs and increased incomes from higher FFB or other crop yields.

However, there are a significant number of non-plantation based (stand-alone) or off-estate palm oil mills. In such cases, an alternative waste management strategy involving waste prevention or minimisation is needed. For this, a novel evaporation technology has been successfully developed and evaluated. The basis for and the results of this R&D effort are:

- POME contains about 96% water and 4% total solids. About 2%-3% is suspended solids comprising mainly of remnants of the mesocarp of oil palm fruits, and 0.7% is residual oil. By evaporation of POME the water can be recovered and the residual solid concentrate utilised.

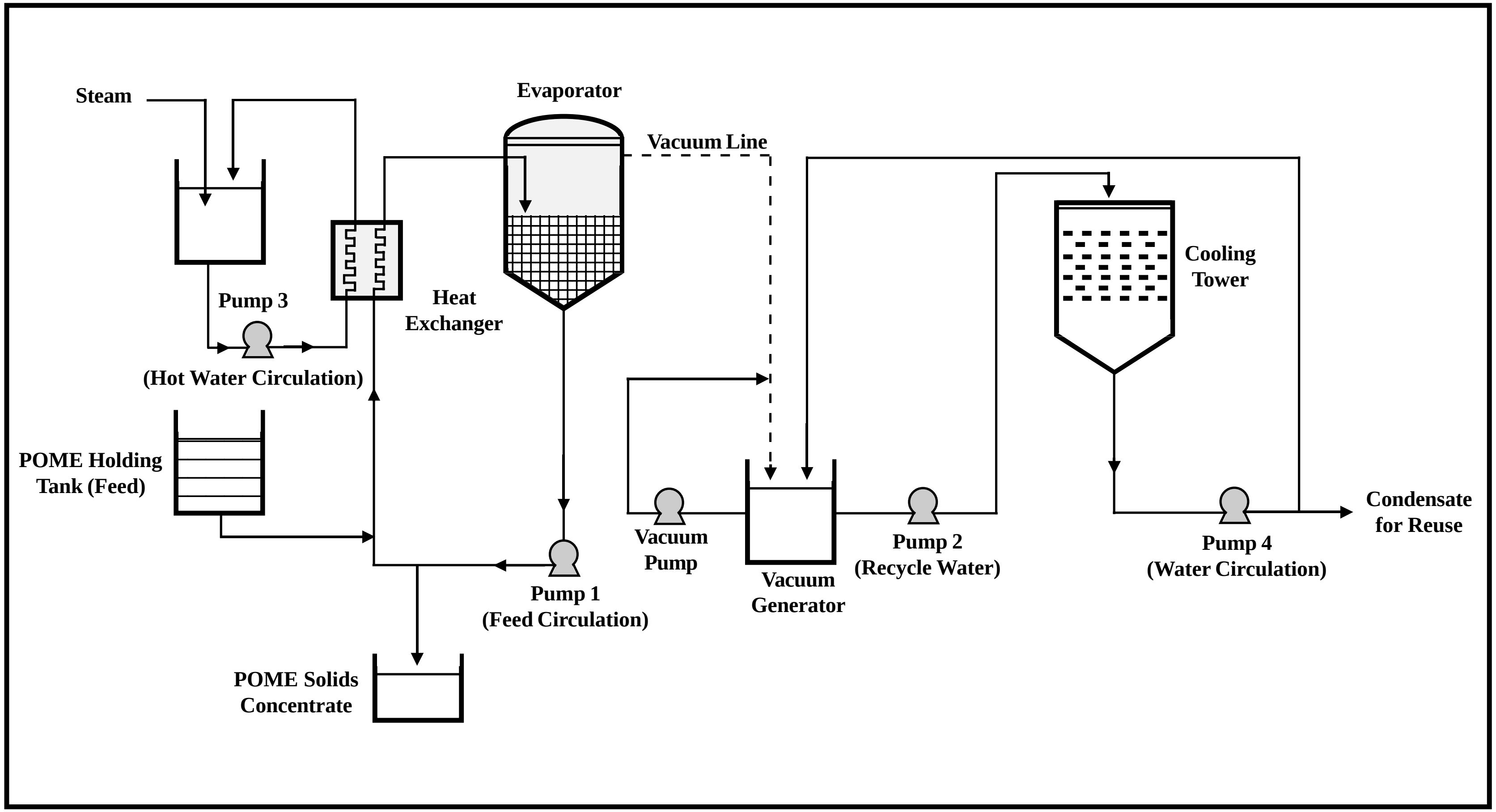


Figure 10 : Evaporation Process for Palm Oil Mill Effluent

- Vacuum evaporation technology was initially evaluated in the laboratory using a rotor evaporator. Efficient evaporation of the water is achieved by taking advantage of the available heat in fresh POME at its average temperature of 80°C and applying a vacuum of 600 mg Hg to lower its boiling point to about 60°C; a clear distillate is obtained.
- The laboratory rotor-evaporator demonstrated that POME can be evaporated to a very dry solid. The laboratory results were confirmed in a pilot plant using a single-effect (flash) evaporator of 200-liter capacity. A schematic flow diagram of the pilot plant is presented in *Figure 10*.
- The maximum solids concentration achieved in the concentrated liquor was about 30%, after which it became too viscous and could no longer be pumped.
- POME used for the pilot trial contained about 3.3% total solids and the solid concentrate produced contained about 20% - 30% solids. Thus, about 85% of the water was evaporated and recovered.
- The quality of the distillate is considered generally good in terms of the total solids content of less than 150 mg/l. The distillate which is slightly acidic due to the presence of carry-over free fatty acids, which during distillation can be re-used as process water or boiler feed water with minimal additional treatment.
- Based on an 85% water recovery rate, a 30-tonne FFB per hour mill which generates about 19.5 tonnes of POME will result in 16 tonnes of water being recovered for recycling. This is sufficient to supply all the boiler feedwater required for the mill operation. If the need arises, the distillate can be mixed with raw water and treated before reuse.
- For the 30-tonne FFB per hour mill, the rate of generation of the effluent concentrate with a solids content of 20% will be about 3.2 tonnes per hour; i.e., a substantial reduction of about 84% from 19.5 tonnes of POME per hour which will result in easier material handling reduction.
- The energy requirement is the major consideration in evaporation. However, the heat required is largely inherent in the fresh POME that is discharged at a temperature of 80°C to 90°C. The additional evaporation energy can be economically derived from the surplus electricity usually generated by palm oil mills, or alternatively from the combustion of empty fruit bunches (EFBs). For mills having excess boiler and electricity-generating capacities the additional investment is minimal.

A commercial-scale evaporation plant is presently under construction and will use a multi-stage evaporation system. It is expected achieve a higher solids concentration in the effluent concentrate due to introduction of a forced-circulation system to pump the concentrated liquid.

The concentrated effluent is rich in plant nutrients, especially nitrogen, phosphorous and potassium. It is therefore a good raw material for making fertiliser. In pilot plant trials, granular fertiliser has been produced successfully while the presence of small quantities of oil did not affect product quality. The solids concentrate also contains about 13.5% of essential amino acids. Thus, it can potentially be used for making other products like animal feed, or as a feedstock for fermentation products.

Evaporation Plant

6.4 CONTROL OF AIR EMISSIONS IN PALM OIL MILLS

Air emissions in palm oil mills are mainly from the boilers and incinerators. The boilers use palm fibre and shell material as fuel, while incinerators have been traditionally used to burn the empty fruit bunch (EFB) for recovery and use of potash as a fertiliser substitute. Therefore, the air emissions from both sources primarily consist of various combustion gases and airborne particulates (condensed tar droplets and soot which are typically in the 20 to 100 micron size range).

6.4.1 Control of Boiler Air Emissions

The boiler air emissions appear as dark smoke due to the presence of soot resulting from the incomplete combustion of the palm fibre and shell material used as fuel. The extent of control of the smoke emission depends largely on the type and age of the boiler. Old boilers may need to be replaced as redesign is costly. Some degree of control of the fuel combustion and smoke emission can be accomplished by striving for steady-state conditions for boilers. The control measures include:

- Use of appropriate indicative boiler instrumentation.

  These include air pressure gauge, steam pressure gauge, carbon dioxide meter and smoke density monitor to indicate completeness of combustion. A carbon dioxide level of about 15% to 20% is indicative of complete combustion, while lower levels indicate incomplete combustion.

- Automated fuel feed.

  The steam demand of the milling processes is variable and automated fuel feed control is necessary to cope with the changing steam demand as well as to maintain steady-state combustion conditions.

- Boiler modification, including

  - Prevention of air leakage from the boiler furnace door;
  - Larger capacity draught fans to increase air injection;
  - Installation of air nozzles for secondary air supply;
  - Replacement of manual fuel feed with automated feed system;
  - Increased stack height for improved pollutant dispersion.

- Installation of dust collectors and other control devices, including

  - Cyclone separators of the single stage (40-50% efficiency), multi-stage (70-85% efficiency), or irrigation-type cyclone units requiring boiler stack air emission velocities of 10-25 meters per second;
  - Bag filters; and
  - Wet scrubbers.

6.4.2 Control of Incinerator Air Emissions

Palm oil mills are discouraged from using empty fruit bunch incinerators in favour of empty fruit bunch mulching within the oil palm inter-rows. In the mulching technique, the mulched bunches are placed in rows between the oil palm trees and allowed to decompose naturally. In relatively flat terrain mulching is conveniently carried out by using tractors to transport and deposit the bunches in the oil palm inter-rows. Empty bunch mulching has the advantage of slow release of the nutrients to the soil and this reduces loss of nutrients due rainfall washout as compared to incineration and application of recovered potash. Mulching is particularly beneficial in plantations with sandy soils. The fertiliser savings resulting from the application of empty bunch mulching have been shown to be very attractive.

An additional advantage of empty bunch mulching is gained by disposing of palm oil sludge and treatment plant sludge onto the deposited empty bunches. This co-disposal of empty bunches and various sludges onto the plantation land enhances the empty bunch biodegradation process as well as soil fertilisation.

In the case of empty bunch incinerators, it is difficult to control the air emissions through the use of dust collectors due to low gas temperatures and gas emission velocities. The only practical approach to particulate emission control is through proper incinerator design and improved combustion efficiency that is achievable by introducing mechanised feeding of empty bunches.

7.0 POLLUTION PREVENTION AND THE CLEANER PRODUCTION APPROACH

7.1 INTRODUCTION

It is inevitable that some waste is generated by all human activities. However, the quantity and the toxicity of the waste released into the environment can be reduced. End-of-pipe waste treatment, which has been the emphasis until quite recently requires additional input of materials, energy and processes that often result in residual waste and further disposal costs. A far more sensible strategy is to minimise the amount of waste generated at source so that the end-of-pipe treatment cost as well as the cost of ultimate disposal of residual wastes can be substantially reduced. In many instances the waste can be recycled or valuable materials reclaimed for reuse.

Over the last two decades, several treatment and disposal technologies have been successfully developed and used to treat palm oil mill effluent (POME). They have been designed to meet the general regulatory limit of 100 mg/1 for effluent BOD_3. The treatment technologies consist of conventional biological systems using anaerobic and aerobic or facultative processes. When adequately designed, well-maintained and operated according to the prescribed operating criteria, the treatment systems are able to treat POME to meet the effluent standards ordinarily imposed by the Department of Environment.

Due to increasing public awareness of environmental pollution and deteriorating water quality of the waste-receiving rivers and streams, especially in river water-supply catchment areas, the DOE has had to impose more stringent discharge limits for palm oil mills and other industries – even zero-discharge in the most environmentally sensitive watersheds.

Biological treatment systems need proper maintenance and close monitoring in view of their reliance on micro-organisms to break down pollutants. The micro-organisms are very sensitive to changes in their environment and great care is needed to prevent an upset of the respective biological processes. This requires the attention of skilled operators as well as the commitment of management. Unfortunately, this is sometimes lacking in the palm oil industry as wastewater treatment is often viewed as an unproductive task and given the lowest priority in the maintenance budget. As a result, palm oil mills are not always able to comply consistently with the effluent discharge standards.

In recognising that environmental protection demands are always on the up-trend, the palm oil industry is also attempting to keep abreast of developments by closely monitoring their operations in search of cleaner production technologies. Serious consideration is being given to process innovations that can be incorporated into existing production lines to minimise or prevent waste generation at source. In general, palm oil mills have been able to accomplish significant progress through adoption of the following elements of pollution prevention and cleaner production:

- Minimisation of waste generation at source through in-plant control and housekeeping measures;
- Resource recovery and utilisation;
- Recycling of water and waste constituents;
- Cost-effective improvements of end-of-pipe solutions.

7.2 CLEANER PRODUCTION IN THE CRUDE PALM OIL INDUSTRY

7.2.1 The Cleaner Production Approach

Since the commencement of strict environmental control of the crude palm oil industry in the late 70's, palm oil mills have progressively introduced improved in-plant control and housekeeping measures to minimise waste generation and the cost of waste management. The specific cleaner production measures that have been successfully adopted are:

- Control of water usage;
- Control of oil clarification temperature;
- Control of oil spillages and leaks;
- Proper design and operation of oil traps;
- Separation of effluent and stormwater drainage systems; and
- Proper interim storage of solid waste materials.

The industry has also adopted improved end-of-pipe solutions as well as better techniques of waste utilisation including cropland application of POME.

7.2.2 Control of Water Usage

Palm oil mills that practise good water usage require less than 1.5 cubic meters of clean water per tonne of FFB processed. Field observations indicate that excessive water usage is attributed to the factors as presented in *Table 6*.

Table 6 : Cleaner Production Measures for the Control of Water Usage

CAUSES OF EXCESSIVE WATER USAGE	CLEANER PRODUCTION MEASURES
Failure to shut off valves, water taps and water hoses immediately	- Proper staff supervision is needed. - Spring-loaded water hoses can be used to resolve these problems.
Tank overflows, especially in the press room and clarification station, due to lack of overflow control	- Level or float controllers need to be installed in all water and oil storage tanks. - Containment system installed at the base of the tank.
Poor equipment maintenance and significant oil leaks leading to excessive washdown	- Need for improved preventative maintenance.
Improper operation of the hydrocyclones resulting in excessive water usage	- Operators need to be better trained to ensure awareness and skilled operation
Use of water to flush out spillages of oil and solid waste materials into drains	- Spilled oil should first be recovered and dry removal/cleaning of remnants practised. - Solid waste spillages should be removed in a dry condition without use of water.
Leaks in water pipelines and valves.	- Regular maintenance is needed.

7.2.3 Control of Oil Clarification Temperature

A crude oil temperature of 90 ^{o}C or more in the continuous settling tank (gravity clarifier) is essential for effective oil separation and minimal loss to the sludge/water phase (should not exceed 10% oil content). Excessive amount of oil in the underflow sludge (sludge oil exceeding about 10%) will result in poor oil separation and recovery in the subsequent sludge centrifuge separator due to overloading; the result is increased oil loss and higher oil content in the clarification wastewater (separator sludge) which should not exceed about 1%.

7.2.4 Control of Oil Spillages and Leaks

Oil spillages and leaks can be quite significant, especially, in the press station and the oil clarification station due to poor equipment maintenance and improper operation. These conditions not only lead to excessive oil losses but also contribute to extremely high waste treatment loads and treatment costs. Regular preventative maintenance and strict operator supervision are needed to minimise such occurrences.

7.2.5 Proper Design and Operation of Oil Traps

Good design and the proper operation of oil traps are important as in-plant measures to enable oil recovery and minimise oil losses before the waste load reaches the wastewater treatment plant. Oil traps may be located in individual stations such as the press room and clarification station. However, a single well-designed oil trap may also be used to remove residual oil from the combined steriliser condensate and clarification station wastewaters. The oil trap should be designed for a hydraulic retention time of at least one(1) day and provided with an adequate number of baffled compartments to enhance turbulent mixing and release of oil to the wastewater surface for removal.

The temperature of the combined steriliser condensate and clarification station wastewaters is usually about 80 to 90 ^{o}C, and at this temperature the oil is able to separate out from the wastewater quite easily. Some mill operators also use steam or a hot water jet to further aid oil separation and removal of the floating oil layer.

7.2.6 Separation of Effluent and Stormwater Drainage Systems

It is not uncommon practice for palm oil mills to have a common set of drains for stormwater and effluent. This can pose a difficult problem in relation to effluent treatment, particularly in tropical climates where intensive rainfall often results in a surge of stormwater entering the effluent drains and the treatment system. The sudden surge of stormwater, especially during initial rainfall, will cause excessive dilution of the effluent as well as washout of the essential active biomass from the treatment system. The net result is a recurrent drop in treatment efficiency following periods of intense rainfall.

This problem is further compounded in the case of plantation industries, where the effluent drainage system may traverse a long distance from the factory site to the effluent treatment system which is usually located on plantation land some distance away.

In order to avoid this problem, it is crucial that a separate system of drains be provided for collecting and transporting the effluent from the milling operations to the treatment system. It is also important to ensure the following:

- Roofs of factory buildings are properly equipped with perimeter rainfall gutters and drain pipes to channel the rainfall to the stormwater drainage system;
- Stormwater from the factory yard, paved areas and plantation land is prevented from entering the effluent drainage system, especially in the case of open effluent drains.

7.2.7 Proper Interim Storage of Solid Waste Materials

The following solid waste materials are generated and sometimes stored temporarily at interim sites in the factory before being moved to long-term storage facilities for use or ultimate disposal:

- Empty fruit bunches (EFB);
- Mesocarp fibre and shell; and
- Decanter and sludge centrifuge solids and residues; and
- Boiler and incinerator ash.

It is important to ensure that during interim storage of these materials they do not gain access into effluent or stormwater drainage systems. The areas in which these materials are temporarily stored should be away from drains, and it is preferred that these areas are provided with containment measures and sheltered from rainfall. The objective is to prevent these materials from finding access into effluent or stormwater drains and contributing to the pollution load entering the wastewater treatment systems or public watercourses.

7.3 WASTE UTILISATION AND RECYCLING

7.3.1 Cropland Application of Treated POME

Over the last 10 years, the management of palm oil mill effluent has evolved from ‘treatment of a waste for disposal’ to ‘beneficial utilisation of an asset’. POME contains substantial quantities of valuable plant nutrients as per the data presented in *Table 2 and 3 in Section 4*. However, the nutrient composition of treated POME will vary according to the degree of treatment to which it is subjected. As a result of the available nutrients, the cropland application of partially treated POME can substantially reduce the inorganic fertilizer requirement of the oil palm plantation or other croplands. However, the rate and frequency of application must be controlled and monitored closely to ensure optimum plant uptake and utilisation, as well as absence of any adverse effects on the environment.

The cropland application of POME has become a standard practice for mills located on or near plantation land. Substantial savings in fertiliser costs and increased incomes from higher crop yields have been reported. The principal land application systems that have been developed and applied are those described in *Section 6*. However, such practice is only applicable to mills with available plantations nearby.

➡ **Partially Treated POME is used in the oil palm plantation as a fertiliser supplement**

7.3.2 Production of Fertilizer and Animal Feed

Another innovative approach to utilization of POME involves modification of the oil clarification process by incorporating a decanter to enable two (2) or three (3) phase separation of the oil, water and solids. With a decanter that enables three (3) phase separation, the resulting wastewater from the oil clarification station has been reduced by about 70%. A decanter solids fraction of about 80% moisture content is produced. A rotary drum drier has been used to further dry the decanter solids to a lower moisture content. Flue gas from the boiler with a temperature of about 300^{o}C has been used as the heating medium to dry the decanter solids down to a moisture content of below 10%. Depending on the ash content of the dried solid matter, it can be made into animal feed or fertilizer.

This preventive approach successfully reduces the volume of POME and its BOD load, as well as eliminates the emission of black smoke and particulates from the boiler.

7.3.3 Recovery of Water and Organic Matter from POME

The potential use of evaporation technology to enable recovery of water from POME, as well as the residual organic solids for conversion to fertiliser or animal feed, was described in *Section 6*. Commercial trial and application of this technology is currently underway. Reclamation of the water and conversion of the solid residual material into saleable value-added products will not only solve the pollution problems but also create a business opportunity.

The successful integration of this evaporation technology for POME into the palm oil milling process via optimum energy usage would result in a closed-loop production system with no

liquid effluent discharged. This would lead to almost complete utilisation of all the by-products and waste materials generated by palm oil mills. The crude palm oil industry would be much closer to being considered as having "clean" technology.

7.4 RELATIVE COSTS OF IMPLEMENTING CLEANER PRODUCTION

Although, there are obvious benefits in implementing cleaner production strategies such as optimum use of resources, reduced wastage and waste generation, reduced production and waste management costs. Nevertheless, cleaner production does entail some cost investments. Certain elements of cleaner production are relatively low cost, while others may involve high capital investments. Thus, in considering the benefits that will accrue, one must also look at the respective payback period for investments in the course of decision-making.

Figure 11 is a graphical representation of the relative costs of various elements of cleaner production. It can be seen that elements such as rational use of resources, good housekeeping, and recycling ordinarily do not involve high costs. However, cleaner production equipment and process modifications can involve high investment costs. Even in the adoption of the cleaner production elements involving significant costs, the assessed benefits and savings that contribute to a reasonable payback period should be able to justify the investments involved.

In approaching the implementation of cleaner production it is first necessary to have a comprehensive environmental audit of the processes performed by suitably qualified people. This can be done by the company's own personnel if they are appropriately trained to do so. If there is no internal lead auditor available, then the facility operator may be encouraged to seek the assistance of an external lead auditor to work along with the company's personnel as a team.

Despite the various developments and accomplishments related to cleaner production in crude palm oil mills, there is still room for extending implementation of the measures across the industry. Many mill owners still need to be convinced of the attractive payback periods on cleaner production investments before they are willing to proceed with implementation.

7.5 ADDRESSING FACTORY CONSTRAINTS

It is commonly perceived that factories are faced with various constraints in wanting to implement pollution control. Given that there are significant production cost-savings and benefits that can accrue by implementing the cleaner production measures identified in this Handbook, it appears that the factory constraints often cited are due to lack of knowledge of the available measures. Many of the perceived factory constraints can be addressed using the arguments presented in *Table 7*.

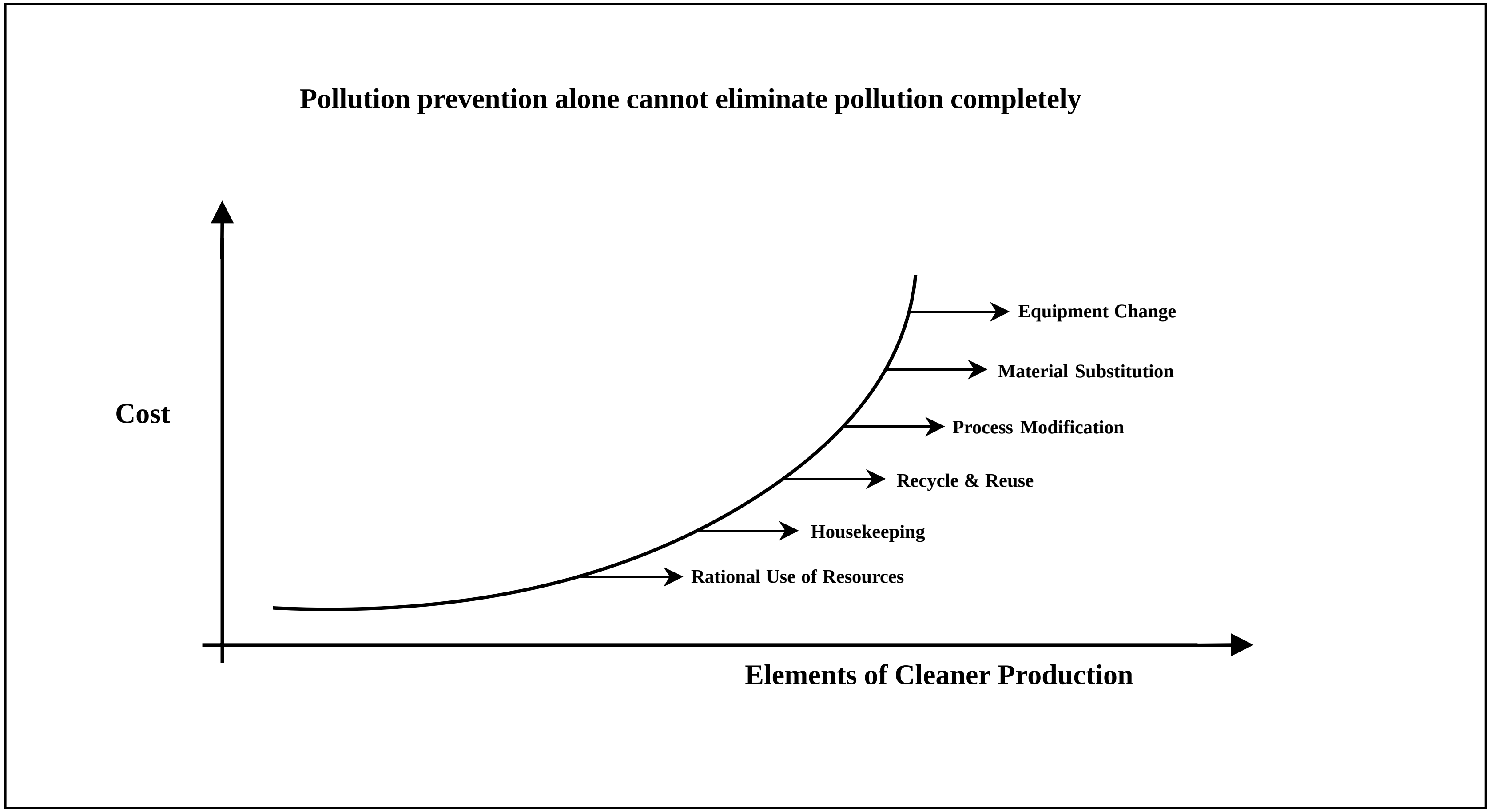
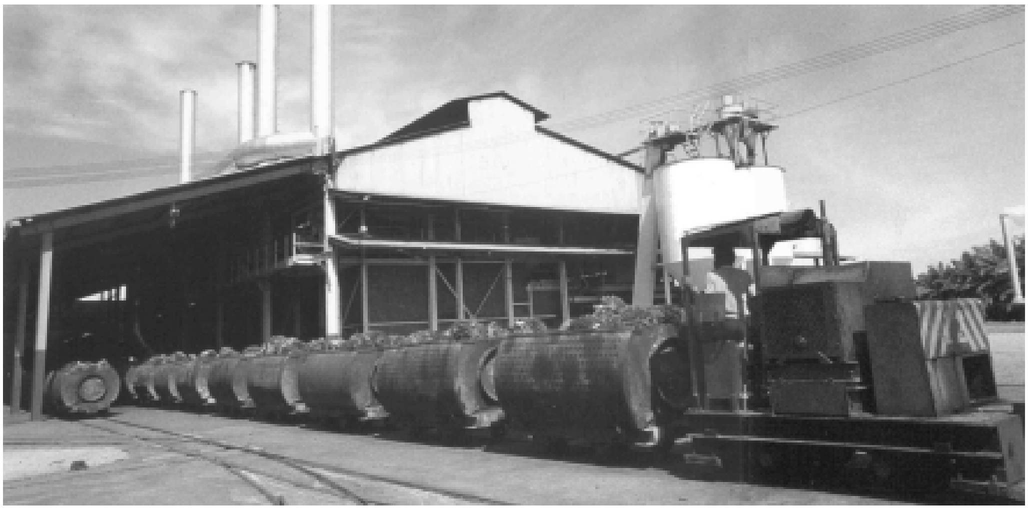


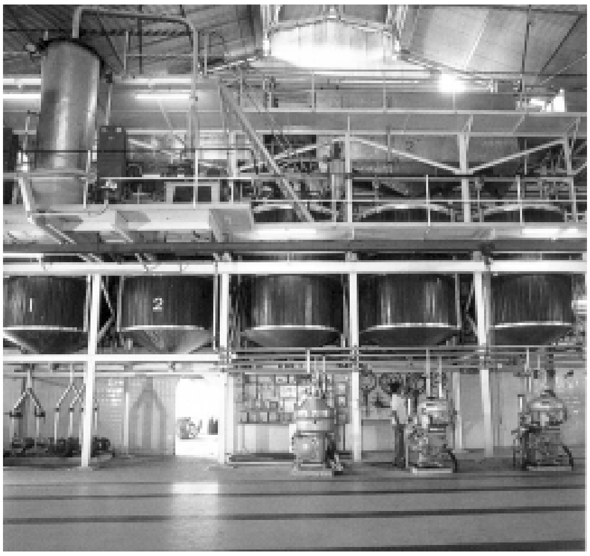
Figure 11 : Relative Costs of Various Elements of Cleaner Production

Table 7 : Addressing Factory Constraints

FACTORY CONSTRAINTS	COUNTER ARGUMENTS
No profit in pollution control	Profit margin can be expected to increase due to increased oil recovery and reduced oil losses, reduced consumption of water and water treatment chemicals, reduced wastewater treatment cost, reduced fertiliser cost, and disposal cost for solid wastes and sludges.
	Market potential may be enhanced due to improved product quality.
Space limitation for installing CP measures and/or wastewater treatment plants	In general, improved cleaning and maintenance procedures do not require separate dedicated space.
High cost of land and factory space for treatment equipment	In-plant measures require limited space, e.g. control of water and chemical usage, and recycling of process water.
	Highly mechanised treatment systems require less space, but involve higher investment cost.
High treatment equipment cost and recurrent operating cost of treatment	The investment cost can be justified by the cost-savings due to reduced production costs.
Poor payback period	Prices of water and electricity can be expected to increase in the future and thereby the payback time will become more attractive - normally can be brought down to below 2 years.
Difficulty to access financing	Banks responding to the government's promptings are providing end-financing of up to 90%. Many incentive schemes are available to SMIs.
Lack of access to technology	Technical information and guidelines are available from DOE, PORIM and private consultants.
Inadequate waste management skills	Available from PORIM, SIRIM and CP consultants.
	Some CP measures do not require specific waste management skills, but only technical skills to do proper maintenance and modifications of process lines.



Good housekeeping practices reduce wastage of materials and minimise pollution loads



CP practices through proper maintenance of process lines are cost-effective and minimise break-downs, leaks and spills

8.0 INSPECTION FOCUS

8.1 INTRODUCTION

This is a particularly important Section of the Handbook as it attempts to guide the DOE Officers into performing the inspections as effectively and efficiently as possible.

A Manual on Practical Enforcement dealing with the general procedures for pre-inspection preparation, comprehensive inspection, and follow-up of inspection visits has been developed separately to assist DOE Inspection Officers in the conduct of their enforcement activities.

This Section on Inspection Focus is industry-specific for crude palm oil mills and serves as a supplement to the Practical Enforcement Manual.

The main purpose of this Section on Inspection Focus is to provide guidance on:

- Essential background information that must be obtained before the inspection;
- Preparation of inspection checklists that enlist essential inspection issues;
- Preparation of recording worksheets to be used during the inspection; and
- Preparation for the closing meeting with the factory management.

8.2 KEY ENVIRONMENTAL ISSUES

The environmental issues of the crude palm oil industry are much less consequential than those of other industries, such as that the metal finishing industry or chemical industries that deal with toxic and hazardous substances. Crude palm oil extraction process essentially involves physical operations and a natural raw material, namely palm oil fruit bunches. It does not require the use of any process chemicals. The main environmental issues of the palm oil industry have been presented in *Section 4*. In summary, the key issues relate to:

- Generation of a highly polluting effluent due to high organic content, especially when high oil losses occur;
- Poor interim storage of solid waste materials and inadequate housekeeping in some mills;
- Smoke emissions from boilers and incinerators; and
- Objectionable odours from inadequately managed treatment lagoons and land-application systems for POME disposal.

8.3 INSPECTION OBJECTIVES

The main objectives of the multi-media environment-based industrial inspection are:

- To monitor and ensure compliance with the regulatory requirements of environmental legislation;
- To observe the conditions of housekeeping and assess the potential for cleaner production;
- To identify the potential areas for improved waste management and pollution control;
- To identify obvious areas for improved waste treatment and waste utilisation,;
- To investigate sources of public of complaints;
- To draw the attention of the management to potential areas for environmental performance improvement and cleaner production possibilities; and
- To demonstrate the DOE's commitment to enhance and protect the environment, and ensure fulfillment of the objectives and requirements of the EQA.

8.4 INSPECTION PROCEDURE AND STEPS

The principal steps involved in a palm oil mill inspection are:

- Pre-inspection planning and review of available factory background information;
- Factory inspection;
- Closing meeting with the factory management; and
- Reporting and follow-up action.

8.4.1 Pre-inspection Planning and Information Review

It is preferable to conduct the review of the relevant documents before the site inspection. In general, the DOE Officer should review the available documents to gain a better understanding of the key issues involved.

(a) Mill Identification, Location and Existing Environmental Status

The DOE Enforcement Officer will need to familiarise himself/herself with sufficient background information on the palm oil mill to be visited, and this should include:

- Mill identification, location, and landuse of immediate surroundings with the aid of a map;
- Milling capacity, operating hours and age of the mill;
- Terms and conditions in the Schedule of Compliance attached to the DOE “prescribed premises” licence issued under Section 18 of the EQA;
- Status of effluent discharge for at least two preceding quarters based on the Quarterly Return Forms from the mill;
- Findings of previous inspection visits and any recommendations made.

(b) Palm Oil Mill Production Process

Although, the palm oil milling process is quite standard, nevertheless the DOE Officer should take note of any significant variations from the conventional palm oil extraction process and/or machinery modifications in the particular mill to be visited. In general, the information to be reviewed should include:

- Type of palm oil extraction process and machinery:
    - Conventional milling process;
    - Process or equipment modifications;
    - Type of steriliser, e.g. horizontal-type or vertical-type;
    - Type of oil extraction equipment, e.g. hydraulic press or screw press;
    - Type of oil clarification facility, e.g. conventional gravity settler (batch settling systems or continuous settling systems), or alternative use of three-phase or two-phase decanters, etc.
    - Type of crude oil separator - 2-phase or 3-phase centrifuge separator
    - Type of sludge oil separator - 2-phase or 3-phase centrifuge separator
    - Type of kernel-shell separation equipment, i.e. hydrocyclone or clay bath.
- The production capacity and/or production rate in terms FFB, crude palm oil product, and by-product materials, such as palm kernel, EFB, fibre and shell;
- Process flow chart:
    - This is most essential, as it gives all the inputs and outputs, including the effluent discharges. This and the other information referred to above will help the DOE Officer to assess the mass balance himself/ herself, if the factory has not already worked it out for him/ her.

(c) Waste Management Systems

- Drawings of the drainage systems of the factory:
  - This is essential to make sure that the factory has separate drainage systems for *effluent and stormwater management*. If the factory has not got a separate drainage system for stormwater, it is likely that this stormwater will join the effluent discharge and reduce the HRT of the treatment system;
  - Determination of the final point of discharge of effluent from the factory premises is important to routine sampling. The point of discharge should be marked on the effluent drainage plan for clarification in a court case.
- Water-supply and effluent discharge:
  - Source of water-supply including type of flow metering;
  - Data on raw and treated effluent;
  - Type of waste-receiving watercourse and their downstream beneficial uses;
- Engineering drawings, plans and relevant information of the effluent treatment and other waste management systems:
  - These would be useful to verify the principal design features of the systems, to establish the point of discharge and to verify any observed deficiencies needing rectification;
- Air emissions:
  - Information is needed on whether the palm oil mill operates any control systems to reduce smoke emission from its boilers and incinerators and analytical data to establish the efficiency of such systems should be obtained.
  - Air pollution control systems and related information, such as chimney height, stack gas sampling access, boiler capacities, control equipment, etc.;

Much of the needed information may be available in the industry source files maintained by the DOE, particularly in the quarterly reports that the palm oil mill submits to the DOE. If the relevant information is not available in the files, then it should be obtained through the usual mechanisms employed by the DOE.

8.4.2 Factory Inspection

While the palm oil mill inspection primarily aims at compliance-monitoring, waste auditing of the facility should also be performed. The good thing about the palm oil mill process is that it is not complicated, chemicals are not used in the process line, and the mill operation does not generate any hazardous or toxic wastes.

Thus, the palm oil mill inspection is a relatively simple activity and involves the following:

- Opening meeting
- Document review
- Inspection of the premises and treatment facilities (use of inspection checklists and worksheets)
- Effluent sampling and analysis

(a) Opening Meeting

An opening meeting is an important element of the inspection visit. The meeting should be held with the factory management to explain the purpose of the visit and how the inspection will be carried out. In some cases, it may address specific concerns that the DOE Officer may have (e.g. as a result of a complaint the DOE may have received), regarding certain adverse environmental impacts of the mill's operation.

(b) Interview and Document Review

The interview phase of the inspection visit can be an important aspect of the process as the DOE Officer can obtain details not found in records, as well as to familiarise with the mill operation. The success of the interviews will depend on the inter-personal skill of the DOE Officer as well as his technical knowledge.

The interview should be such as to convey the message to the facility management and operators that the DOE Officer has not come as a prosecutor or a judge, but to jointly review the whole operation from an environmental perspective, and to provide guidance to the management on how to improve the operation to achieve greater success in managing the environmental aspects and issues and facilitate compliance with the conditions of licence.

The findings of the interviews should be verified through record checks, site inspection and further interviews, if necessary. Such a step will help the Inspector avoid drawing conclusions of certain matters based on mere hearsay.

During the interviews, documents to be reviewed should include:

- Quarterly returns submitted to the DOE;
- Records of monthly data which were used in preparing the quarterly returns including production data, water consumption, effluent discharge data, etc.;
- Records on air pollution control equipment (dust collector, smoke recorder, etc.) and wastewater treatment facility (WTF) maintenance schedule;
- Relevant analytical data, i.e. the effluent analysis and air emission analysis;
- Records of complaints, if any, and how the mill management resolved the issues involved;
- Treatment process flow diagrams and treatment plant plans

(c) Inspection of Premises (use of inspection checklists and worksheets)

This is the most important aspect of the factory inspection. There are many ways of conducting a site inspection. But the most commonly practised method is the general planned walk-through inspection. The DOE Officer examines everything from the raw material reception area to the dispatch of finished products, using the process flow chart obtained earlier. The DOE Officer should:

- Evaluate housekeeping and in-plant process control.
- Examine the process line, and where possible:
  - inspect all areas, including remote areas;
  - observe operations during times of effluent discharge and air emission; and
  - observe sampling and monitoring procedures.

The process line inspection is mainly to ensure that the effluent generation and discharge points are the same as those shown in the process flow diagram.

- Inspect the effluent treatment plant, and observe for the following:
  - type of treatment system;
  - adequacy of basic design;
  - point of final effluent discharge as specified in the licence;
  - status of operation and maintenance;
  - regularity of sludge removal and sludge return (if any);

- status of compliance with effluent discharge standards;
- any special features of improved design or operation.

The DOE Officer should review the pre-treatment and treatment plant operations by visiting the plants. In some cases, the treatment plants could be far away from the factory, depending on the availability of suitable land for the treatment plant. In some cases, the factory effluent may be utilised for land application in which case the DOE Officer should visit the field to check on the system to see that the operation complies with the general DOE requirements.

To carry out the inspection of the factory premises effectively, the use of checklists is essential for providing guidance, and worksheets to systematically record the observations and findings. For this purpose, two checklists and two worksheets have been developed.

These are:

- Checklist on status of good housekeeping and cleaner production opportunities
- Checklist on status of regulatory compliance
- Recording worksheet on status of good housekeeping and cleaner production
- Recording worksheet on status of regulatory compliance.

(i) *Inspection Checklist on Status of Good Housekeeping and Cleaner Production*

An inspection checklist for good housekeeping is highly necessary to provide guidance and a reminder on what to look for in this area. A comprehensive list is provided in the attached *Appendix 3*. It highlights the production flow sequence and inspection items for each station, including the cleaner production opportunities.

(ii) *Recording Worksheet on Status of Good Housekeeping and Cleaner Production*

The detailed worksheet is provided in *Appendix 4*. It covers the inspection area, observations, evidences taken and findings based on three(3) qualifiers – satisfactory, unsatisfactory and further investigation needed.

(iii) *Checklist on Status of Regulatory Compliance*

This checklist is attached as *Appendix 5* and it contains the final discharge status, regulatory requirements and inspection focus.

(iv) *Recording Worksheet on Status of Regulatory Compliance*

This recording worksheet is attached as Appendix 6 and is for documenting information and data on the status of the final effluent discharge, inspection focus, evidences and findings.

(d) Sampling and Analysis of Palm oil Mill Effluents

The main characteristics of palm oil mill effluents are currently determined by the following parameters:

- Biochemical Oxygen Demand (BOD; 3-Day, 30^{o}C)
- Suspended Solids (SS)
- Oil & Grease (O&G)
- Total Nitrogen (TN)
- Ammoniacal Nitrogen (AN)
- pH
- Temperature (^{o}C)

(i) *Sampling of Palm Oil Mill Effluents*

The basic objectives of representative effluent sampling are:

- To obtain a sample at the DOE-approved sampling point(s), where concentrations of determinants are representative of those in the effluent at the time of sampling; and
- To ensure that the concentrations of the determinants in the samples do not change between sampling and laboratory-based analysis.

If these objectives are not achieved, the analytical results may be partially or completely invalid for their intended purposes. Representative sampling and sampling at the correct sampling point are critical requirements in the case of non-compliance and the need to provide appropriate evidence during court proceedings. In case it is observed that the discharge point used by the mill is not approved by DOE, the effluent should be sampled and it should be ensured that it was possible to prove that the sample is taken from the oil mill effluents and to prove that the effluents were discharged at a point that had not been approved by DOE.

(ii) *Sampling Apparatus*

The type of sampling equipment and apparatus required to obtain representative effluent samples depend on the sampling technique to be employed. Representative sampling techniques include:

- Flow-proportional sampling and compositing of effluent; and
- Time-composite sampling.

Sampling may be performed manually, semi-manually or with the use of automatic sampling equipment consisting of flow monitors and flow proportional samplers. Time-composite samples may be taken manually or with the use of automatic samplers. The apparatus used for sampling may therefore range from simple hand-operated vessels, such as beakers and buckets, to sophisticated automatic devices which take constant volume samples at specified time intervals or, which take sample volumes proportional to the effluent flow rate.

Sample containers should be of material that will not contaminate the sample. Chemical- resistant glass and polyethylene are suitable materials for containers.

Coloured bottles are preferred for BOD test samples as they limit light penetration and consequently inhibit microbial activity which can otherwise change the effluent characteristics prior to testing.

All sample containers should be provided with stoppers, caps or plugs of suitable material that can resist the attack by the vessel's contents. Containers should be carefully cleaned before use to remove all extraneous surface dirt. Before filling, the sample container should be rinsed out two or three times with the effluent to be sampled.

(iii) *Sampling Techniques*

The chemical analysis is generally intended to reveal the composition of the effluent at the time of sampling. As the composition of effluent varies with time, it will be more appropriate that a time-composite sample be taken for chemical analysis in order to represent an average condition of the total effluent discharged for the day of production.

In order to get a time-composite sample, a minimum of six individual samples should be collected at regular time intervals over a minimum period of one 8-hour shift during the operation of the factory. The individual samples taken should be refrigerated immediately to 4^{o}C and kept at this temperature during the compositing period. At the end of the compositing period, the composite sample should be mixed thoroughly and a suitably-sized portion taken for performance of the chemical analysis. Usually a 1-litre portion of the composite sample is sufficient for a complete effluent analysis. This sampling technique is very good for implementation by the mill management for purpose of maintenance of the wastewater treatment facility. For the purpose of routine effluent monitoring and determining regulatory compliance, instant grab sampling at the DOE-approved sampling point is sufficient.

The sampling point for the factory effluent should be carefully chosen to ensure that the total combined factory effluent that is finally discharged from the factory premises is being sampled. This is the point at which the effluent emerges from the premises or treatment plant or the point prior to the discharge of effluent into a watercourse or any soil or surface of land. The sampling point must be approved by the DOE.

A record should be made of every sample collected and each sample should be clearly labeled using the standard label of the DOE/ Chemistry Department. The record should contain sufficient information to provide positive identification of the sample as well as the name of the sample collector, the date, time and exact sample location, the weather condition and any other data which may help in the interpretation of the analytical results.

(iv) *Sample Preservation*

Because of likely changes that take place on standing, it is desirable that analyses be made as soon as possible after collection of samples. However, this is not always feasible as palm oil mills are usually located far from effluent laboratories. In order to prevent, or at least to minimise the changes in their properties, the effluent samples should be preserved according to the techniques given in *Table 8*. However, POME samples are usually preserved by refrigeration at $4^{o}C$, or by adding acid to bring down the pH of the sample to about 2.0 to minimise microbial activities of the sample.

8.4.3 Closing Meeting

The closing meeting should be held with the factory management following the inspection of the factory premises and the treatment plant, and after the DOE Officer has had time to note the main points for presentation and discussion.

The closing meeting should aim at accomplishing the following:

- Sum up the observations and findings;
- Ensure a common understanding on the findings to avoid any misunderstanding;
- Enhance the environmental awareness of the factory personnel;
- Explain and issue compounds, if necessary;
- Inform the management of any needed follow-up action in response to areas of non-compliance;
- Arrange for a follow-up visit, if necessary;

- Discuss possible improvements of the factory's good housekeeping, treatment system, etc.;
- Clarify and confirm any agreement recorded; and
- Discuss any other matters of mutual interest or concern.

Table 8: Parameter-Based Preservation Techniques for POME Effluent Samples

PARAMETER	PRESERVATION TECHNIQUE	MAXIMUM HOLDING PERIOD
BOD	Refrigeration at 4 ^oC	6 hours
Suspended Solids	None available	7 days
Oil & Grease	Add 5 ml concentrated H_2SO_4/litre (pH<2) and refrigeration at 4 ^oC	1 month
Total Kjeldahl Nitrogen	Add 40 mg $HgCl_2$/litre sample at 4 ^oC	Unstable
Ammoniacal Nitrogen	Add 40 mg $HgCl_2$/litre sample at 4 ^oC	7 days

Note: Sample containers made of glass are preferred.

8.4.4 Reporting and Follow-up Action

The main purposes of reporting and follow-up action are to ensure that:

- All information and data collected are well-documented, registered, filed and used appropriately;
- Suggestions on further actions are taken to enhance compliance;
- The facility operator and the management are aware of the requirements for any needed improvement of their environmental performance; and
- DOE's general commitment to enforcement of the EQA is well demonstrated.

Further information on reporting and follow-up action can be found in the ***Practical Enforcement Manual***.

APPENDIX 1

ENVIRONMENTAL QUALITY (CLEAN AIR) REGULATIONS 1978

AIR EMISSION STANDARDS

	SUBSTANCES EMITTED	STANDARDS		
1.	Solid particle concentration in the heating of metals	Standard A : 0.3 gm/Nm^3 Standard B : 0.25 gm/Nm^3 Standard C : 0.2 gm/Nm^3		
2.	Solid particle concentration in the heating of metals	Standard A : 0.6 gm/Nm^3 Standard B : 0.5 gm/Nm^3 Standard C : 0.4 gm/Nm^3		
3.	Metals and metallic compounds:	Std. A gm/Nm^3	Std. B gm/Nm^3	Std. C gm/Nm^3
	Mercury	0.02	0.01	0.01
	Cadmium	0.025	0.015	0.015
	Lead	0.04	0.025	0.025
	Antimony	0.04	0.025	0.025
	Arsenic	0.04	0.025	0.025
	Zinc	0.15	0.1	0.1
	Copper	0.15	0.1	0.1

	SUBSTANCES EMITTED	SOURCES OF EMISSION	STANDARDS
4(a)	Acid Gases	Manufacture of sulphuric acid	1. Equivalent of : Standard A : 7.5 Standard B : 6.0 Standard C : 3.5 gram of sulphur trioxide/ Nm^3 of effluent gas 2. Effluent gas free from persistent mist
(b)	Sulphuric acid mist or sulphur trioxide or both	Any source other than combustion process and plant for manufacture of sulphuric acid as in (a) above	1. Equivalent of : Standard A : 0.3 Standard B : 0.25 Standard C : 0.2 gram of sulphur trioxide/Nm^3 of effluent gas. 2. Effluent gas free from persistent mist
(c)	Chlorine gas	Any source	Equivalent of : Standard A : 0.3 Standard B : 0.25 Standard C : 0.2 gram of hydrogen chloride/ Nm^3

	SUBSTANCES EMITTED	SOURCES OF EMISSION	STANDARDS
(d)	Hydrogen chloride	Any source	Standard A : 0.6 Standard B : 0.5 Standard C : 0.4 gram of hydrogen chloride/ Nm^3
(e)	Fluorine, hydrofluoric acid, or inorganic fluorine compound	Manufacture of aluminium from alumina	Equivalent of : Standard C : 0.02 gram of hydrofluoric acid/ Nm^3 of effluent gas
(f)	Fluorine, hydrofluoric acid, or inorganic fluorine compound	Any source other than manufacture of aluminium from alumina as in (e) above	Equivalent of: Standard A : 0.15 Standard B : 0.125 Standard C : 0.100 gram of hydrofluoric acid/ Nm^3 of effluent gas
(g)	Hydrogen sulphide	Any source.	Standard A : 6.25 Standard B : 5.00 Standard C : 5.00 parts per million volume for volume
(h)	Oxide of nitrogen	Manufacture of nitric acid	Equivalent of: Standard A : 4.60 Standard B : 4.60 Standard C : 1.7 effluent gas substantially colourless gram of sulphur trioxide/ Nm^3
(i)	Oxide of nitrogen	Any source other than combustion processes and manufacture of nitric acid as in (h) above	Equivalent of: Standard A : 3.0 Standard B : 2.5 Standard C : 2.0 gram of sulphur trioxide/ Nm^3

5.	Dust and solid particles	Std. A gm/Nm^3	Std. B gm/Nm^3	Std. C gm/Nm^3
	Asphalt Concrete Plant			
	Stationary Plant	0.5	0.4	0.3
	Mobile Plant	0.7	0.7	0.4
	Portland Cement Plant			
	Kiln	0.4	0.2	0.2
	Clinker, cooler finish, grinding and others	0.4	0.2	0.1
6.	Asbestos and free silica	0.4	0.2	0.12

APPENDIX 2

ENVIRONMENTAL QUALITY (CLEAN AIR) REGULATIONS 1978 THIRD SCHEDULE

NOXIOUS AND OFFENSIVE SUBSTANCES [Regulation 32]

Muriatic acid
Sulphuric acid and sulphuric anhydride
Sulphurous acid and sulphuruos anhydride
Nitric acid and acid forming ozides of nitrogen
Chlorine and its acid compounds
Bromine and its acid compounds
Iodine and its acid compounds
Fluorine and its compounds
Arsenic and its compounds
Ammonia and its compounds
Cyanogen and its compounds
Pyridine
Bisulphide of carbon
Chloride of sulphur
Acetylene
Sulphuretted hydrogen
Volatile organic sulphur compounds
Fumes from benzene works
Fumes from cement works
Fumes from fish manure works
Fumes from pesticides formulating and manufacturing works
Fumes from asbestos product works
Fumes from tar works
Fumes from paraffin oil works
Fumes containing copper, lead, antimony, arsenic, mercury, zinc, aluminium, iron, silicon, calcium or their compounds
Smoke, grit and dust

Fumes containing uranium, beryllium, cadmium, selenium, sodium, potassium or their compounds

Carbon monoxide

Acetic anhydride and acetic acid

Aldehydes

Amines

Fumes containing chromium, magnesium, manganese, molybdenum, phosphorus, titanium, tungsten, vanadium or their compounds

Maleic anhydride, maleic acid and fumaric acid

Products containing hydrogen from the partial oxidation of hydrocarbons

Phthalic anhydride and phthalic acid

Picolines

Fumes from petroleum works

Acrylates

Di-isocyanates

Fumes containing chlorine or its compounds

APPENDIX 3

Inspection Checklist on Status of Good Housekeeping and Cleaner Production

No.	Production Flow Sequence	Model Situation	Inspection Focus
1.	Raw materials reception areas for fresh fruit bunch	• Areas clean, tidy and free of accumulation of bruised fruits and rotten empty bunches	**Look-out for:** • Crushing of loose fruits • Oil and dirt accumulation **Cleaner Production Opportunities:** • Cleaning of reception areas after unloading of FFB with pressure hose • Removal of dirt and other unwanted materials
2.	Loading of FFB into cages	• Clean and tidy area • Provision for spillage containment • Proper loading system based on first come first load principle	**Look-out for:** • Over-filling of cages **Cleaner Production Opportunities:** • Recover EFB and loose fruits on ground • Remove all dirt and waste materials

No.	Production Flow Sequence	Model Situation	Inspection Focus
3.	Control of water usage	• Less than 1.5 m^3/tonne FFB processed	**Look-out for:** • Water faucets and hoses kept open when not in use • Leaking pipe joins, valves and faucets **Cleaner Production Opportunities:** • Flow metering of water consumption and effluent discharge • Installing float valves/ cut-off switch for water tanks • Training of factory operators in good housekeeping
4.	Control of oil clarification temperature	• Not less than 90^{o}C in batch or continuous settling tank	**Look-out for:** • Poor oil separation and excessive losses to clarification station wastewater • Under-flow sludge from static settling tank should have less than 10% oil content Clarification effluent from sludge centrifuge separator should have less than 1% oil content **Cleaner Production Opportunities:** • Improved temperature control in crude oil settling tanks to minimise oil losses to clarification station wastewater

No.	Production Flow Sequence	Model Situation	Inspection Focus
5.	Control of oil spillages and leaks	• Proper preventative maintainence and speedy response in the event of oil spill occurences	**Look-out for:** • Oil storage tank overflows and absence of level controllers • Leaking pipes and appurtenances **Cleaner Production Opportunities:** • Minimum oil losses to wastewaters and reduced organic loading of treatment facilities
6.	Proper design and operation of oil/fat traps	• Good design of oil/ fat traps with minimum HRT of about 1 day	**Look-out for:** • Basic design dimensions and features and determine the HRT • Poor oil separation and high oil content in effluent **Cleaner Production Opportunities:** • Minimum oil losses to wastewaters and reduced organic loading of treatment facilities

No.	Production Flow Sequence	Model Situation	Inspection Focus
7.	Proper design of boiler and dust scrubbing system	• Incorporated with dust scrubber, appropriate chimney height and stack gas sampling access, boiler feeding system and smoke detector/recorder	**Look-out for:** • Sampling port, platform, ladder and chimney height • Smoke detector analysis and maintenance schedule • Fuel feeding system • Scrubber maintenance record and efficiency test • KWh-readings (after turbine) fluctuation
8.	Proper interim storage of solid by-product and waste materials	• Storage areas should be away from drains and preferably sheltered from rainfall and provided with containment bunds	**Look-out for:** • Solid waste and by-product materials and residues finding access into stormwater or effluent drains **Cleaner Production Opportunities:** • Absence of solid waste materials in drainage systems reflects good housekeeping

No.	Production Flow Sequence	Model Situation	Inspection Focus
9.	Stormwater and effluent drainage systems	• The two drainage systems working independently • Both systems at a satisfactory level	**Look-out for:** • Mixed drainage system • Maintenance of this drainage system • Clogging of the drains **Cleaner Production Opportunities:** • Maintenance of a good drainage system reflects good housekeeping being practised in the factory
10.	Stabilisation (Compositing) of effluent	• The provision for a stabilisation (compositing) tank/pond with 1-day HRT, after the oil/fat trap(s) is desirable	**Look-out for:** • Absence of a stabilisation (compositing) pond/tank due to lack of space or cost-saving intentions • Minimum HRT of 12 hours and preferably 24 hours • Oil build-up in stabilisation (compositing) pond is an indication of poor operation of the oil traps **Cleaner Production Opportunities:** • A stabilisation (compositing) pond/tank helps to prevent the shock-loading of the treatment system • Under emergency situation, it provides temporary storage facility • If liming is necessary to improve the pH of effluent before the treatment, it provides a homogeneous input

No.	Production Flow Sequence	Model Situation	Inspection Focus
11.	Treatment System • Biological ponding: - Anaerobic - Facultative - Aerobic • Land disposal: - Sprinkler system - Shallow bed - Etc.		**Look-out for:** • Smell • Scums • Overflows

APPENDIX 4

Recording Worksheet on Status of Good Housekeeping And Cleaner Production

Name of Factory : ______________________

Address : ______________________

____

____

Date of Inspection : ______________________

Time of Inspection : ______________________

Legend:

Evidence
Photos (P)
Factory Records (FR)
Samples (S)

Findings
S : Satisfactory
US : Unsatisfactory
F : Further Investigation needed

Please tick [✔] where applicable.

Inspection Area	Observation	Evidence Taken	Findings
1. Raw materials reception area for FFB		P FR	S US F
2. Loading of FFB		P FR	S US F
3. Control of water usage		P FR	S US F
4. Control of oil clarification temperature		P FR	S US F
5. Control of oil spillages and leaks		P FR S	S US F
6. Design and operation of: - oil/ fat traps - anaerobic tank/ponds - pumps stations		P FR	S US F

Inspection Area	Observation	Evidence Taken	Findings
7. Interim storage of solid by-product and waste materials		P FR S	S US F
8. Separate stormwater and effluent drainage systems		P FR	S US F
9. Stabilisation (Compositing) of POME - pH and temperature adjustment - recirculation and overflow		FR S FR S	S US F S US F
10. Solid waste disposal		P FR	S US F
11. POME disposal	Treated	P FR	S US F
	Untreated	P FR	S US F
12. Air emissions	Treated	P FR	S US F
	Untreated	P FR	S US F

DOE Officer

Name : ______________________________

Designation : ______________________________

Date : ______________________________

APPENDIX 5

Inspection Checklist on Status of Regulatory Compliance

Final Discharge Status	Regulatory Requirement	Inspection Focus
1. Effluent discharge	Compliance with prevailing effluent standards presented in Table 4 of Section 5, and/or other effluent parameter limits imposed as conditions of licence in accordance with the Environmental Quality (Prescribed Premises (Crude Palm Oil) Regulations, 1977.	• Evidence of monitoring and analysis of effluent • Sampling location and frequency • Analytical results • Public complainants
2. Air emission	Compliance with the relevant provisions of the Environmental Quality (Clean Air) Regulations, 1978, if any.	• Factory records - Smoke recorder analysis - Stack gas sampling and analysis • Public complainants

APPENDIX 6

Recording Worksheet on Status of Regulatory Compliance

Name of the Factory : ______________________________

Address : ______________________________

____

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Legend:

C : Compliance

NC : Non-compliance

F : Further Investigation needed

Please tick [✔] where applicable.

Final Discharge Status	Inspection Focus	Evidence	Findings
1. Effluent discharge	- pH - BOD (3-day; 30°C) - COD - Total Solids - Suspended Solids - Total Nitrogen - Ammoniacal Nitrogen - Oil & Grease - Temperature	Factory records Samples Photos	C NC F
2. Air emission	- Scrubbing systems	Available Not Available	Satisfactory Unsatisfactory
3. Solid waste	- Disposal of used packing materials - Sludge from oil trap and treatment plants	Visual inspection Photos	Satisfactory Unsatisfactory

DOE Officer

Name : ______________________________

Designation : ______________________________

Date : ______________________________

REFERENCES

1. AHMAD IBRAHIM; YEOH, B G; CHEAH, S C ; MA, A N; CHEW, T Y; RAJ, R and WAHID, M A J (1984). Thermophilic Anaerobic Contact Digestion of Palm Oil Mill Effluent. *J. Water Science and Technology*, 17, : 155 – 166.

2. BOUMANN, S; BRINKMAN, D W; DE JONG, P and WAALEWIJN, R (1998). Multistage evaporation in the dairy industry. In : *Pre-concentration and drying of food materials*, ed. Bruin S, Elsevier.

3. CHAN, K S and CHOOI, C F (1982). Ponding System for Palm Oil Mill Effluent. *PORIM Proc. Of Reg. Worksp. On Palm Oil Mill Techy. And Effl. Treat*. *p*. 185.

4. CHOOI, C F (1984). Ponding System for Palm Oil Mill Effluent Treatment. *Workshop. Proc*. Palm Oi Res. Inst. Malaysia No.9, *p* 53.

5. CHUA, N S and Gian, H L (1986). "Biogas Production and Utilisation – Keck Seng's Experience". Paper presented at National Workshop on Recent Development in Palm Oil Milling Technology and Pollution Control, Kuala Lumpur.

6. CHUA, N S (1991). Optimal Utilization of Energy Sources In a Palm Oil Processing Complex. 1991 PORIM Int. Palm Oil Conf. – Chemistry & Technology. *p.13 – 19.*

7. EC DEMO No. 82 (1990). Concentration of (technical) gelatine using a falling-film evaporator with mechanical vapour re-compression, 1990.

8. FREDRICKSON, D (1984). Hardboard plant evaporator system dramatically cuts treatment costs. *Chemical Processing*, Nov 1984.

9. HANIF JUNIT (1994). Natural rubber serum quality. Seminar Hari Alam Sekitar Pengurusan Effluen Kelapa Sawit dan Getah, Melaka, Dec 1994.

10. KANAGARATNAM, K; LAI, A L; LIM, K H; and WOOD, B J (1981). "Application of POME to Land, Characteristics and Oil Palm Crop", Proc. of Nat. Workshop on Oil Palm By-Product Utilization. pp. 16 – 23.

11. KINKHABWALA, A (1994). Replacement evaporation system saves more than $2,600/ day in net energy costs. *Chemical Processing*, Jan. 1994.

12. LIM, K H (1984). Review of HMPB Effluent Treatment Plants Performance. *Worksp. Proc*. Palm Oil Res. Inst. Malaysia No.9, *p*. 11.

13. LIM K H (1987). "Trials on Long Term Effects of Application of POME on Soil Properties, Oil Palm Nutrition and Yields". Proc. of 1987 Int. O.P./P.O. Conf. – Agriculture, pp.575 – 595.

14. LIM, C H; P'ng, T C; Chan, K W and Chooi, S Y (1983). "Land Application of Digested Palm Oil Mill Effluent by Sprinkler System", Proc. of Land Application of Palm Oil and Rubber Factory Effluents, Malaysian Society of Soil Science, pp. 71-89.

15. LIM, K H; QUAH S K; GILLIES, D and WOOD, B J (1984). Palm Oil Mill Effluent Treatment and Utilization in Sime Darby Plantations – The Current Position. *Worksp. Proc*. Palm Oil Res. Inst./Malaysia, No. 9, *p*. 42.

16. MA, A N and ONG, A S H (1985). Pollution Control in Palm Oil Mills in Malaysia. *JAOCS, 62*, : 261 – 266.

17. MOHD. HASHIM TAJUDIN AND ZIN ZAWAWI ZAKARIA (1984). "Present Status of Land Application of POME", Worksp. Proc. Palm Oil Res. Inst. Malaysia No. 9: 74 – 83.

18. MOHD. TAYEB DOLMAT, LIM, K H; ZIN ZAWAWI ZAKARIA and HALIM HASSAN (1987). "Recent Studies on the Effects of Land Application of Palm Oil Mill Effluent on Oil Palm and the Environment". Proc. of 1987 Int. O.P./P.O. Conf. – Agriculture, pp.596 – 604.

19. QUAH, S K, and GILLIES, D (1981). Practical Experience in Production and Use of Biogas. *Proc. Of Nat. Worksp. On Oil Palm By-Prod. Utilisation*, *p*. 119.

20. QUAH, S K; LIM, K .H; GILLIES, D; WOOD, B J and KANAGARATNAM, J (1982). Sime Darby POME Treatment and Land Application System. *Proc., of Reg. Worksp*. On Palm Oil Mill Techy. & Effl. Treat. *p*. 193.

21. SEABURG J L and BACCHETTI J A (1985). Evaporator concentrates plating rinse for recycle to process. *Chemical Processing*, Nov 1985.

22. TAM, T K; YEOW, K H and PON, Y C (1982). "Land Application of POME". H & C Experience, Proc. of reg. Workshop on Palm Oil Mill Techy. & Effl. Treat. pp. 216 –224.

23. YUNDT B and RHEINESMITH R (1981). Horizontal spray-film evaporation, CEP, *p*. 69 – 73, Sept 1981.

24. YEOH K H; and GURMIT SINGH. (1983). "Land Application of Plantation Effluent". MOPGC/MRPC Internal Report.

25. YEOH, B G; CHEW, T Y; MA, A N; CHEAH, S C; CHOW, M C; RAJ, R; IBRAHIM, A and WAHID, M A J (1986). " Improved Anaerobic Digestion of Palm Oil Mill Effluent Using the Thermophilic Contact Process". Paper presented at PORIM National Workshop on Recent Development in Palm Oil Milling Technology and Pollution Control. 5 – 6 August, 1986, Kuala Lumpur.