Environmental Management for the Palm Oil Industry

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INTRODUCTION

Over the last three decades, the Malaysian palm oil industry has grown to become a very important agriculture-based industry. Currently, there are more than 2.6 million hectares under oil palm and 290 palm oil mills to produce crude palm oil and palm kernel for further processing by refineries, palm kernel crushers and oleochemical companies.

In 1997, Malaysia produced about 9.03 million tonnes of crude palm oil and 1.1 million tonnes of crude palm kernel oil. Processed palm oil and palm kernel oil have become one of the country's major export revenue earner in recent years. Malaysian palm oil accounted for about 52% of the world palm oil output and 9% of world output of 17 major oils and fats. In the same year, the oil palm sector generated RM13 billion export earnings for the country.

Besides crude palm and kernel oils, palm oil mills also generate large volumes of solid by-products and liquid effluent as shown in *Table 1.*

All the by-products require a sound and efficient management system in utilisation, treatment and disposal. Otherwise, they will have a negative environmental impact.

Due to the increasing public awareness on environmental conservation and the deteriorating air and river water quality, the oil palm industry faces the challenge of balancing environmental care with economic viability and human welfare. There is an urgent need to find a way to preserve the environment of our country while keeping her economy healthy.

While profit is the primary objective, the oil palm industry also realises that the environmental regulations are here to stay. Thus, the industry is fully aware that the pollution now must be cleaned up later, and that it is often cheaper to prevent waste at source rather than treat and dispose off later.

Growing awareness of the need to prevent pollution has required the palm oil producers to re-examine their plant operations. A process solution that meets the cost and performance requirements and minimises environmental impact is the preferred choice.

PALM OIL MILLING

A schematic flow of palm oil milling is shown in *Figure 1.* Broadly, it consists of

TABLE 1. ESTIMATED BY-PRODUCTS GENERATED BY PALM OIL MILLS IN 1996

By-Product	Million Tonnes	Moisture Content (%)	Heat value (Dry Basis) (Kcal/Kg)
Fibre	5.8	4.2	4420
Shell	3.7	7.0	4950
Empty Fruit Bunches	9.6	6.5	3700
Palm Oil Mill Effluent	21.0	95.0	–

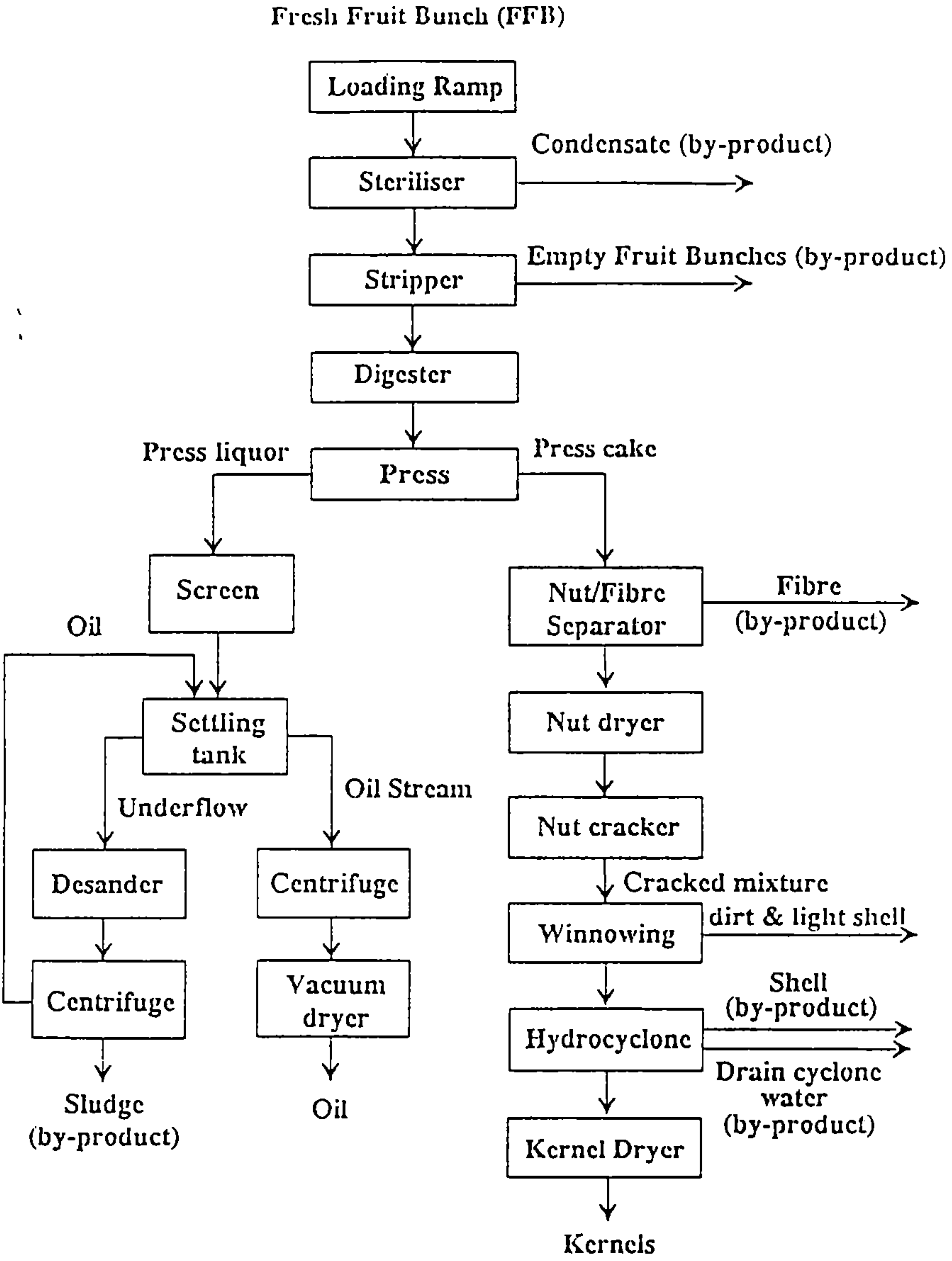
Fresh Fruit Bunch (FFB)
Loading Ramp
Condensate (by-product)
Steriliser
Empty Fruit Bunches (by-product)
Stripper
Digester
Press liquor
Press
Press cake
Screen
Nut/Fibre Separator
Fibre (by-product)
Oil
Settling tank
Nut dryer
Oil Stream
Underflow
Nut cracker
Desander
Centrifuge
Cracked mixture
Winnowing
dirt & light shell
Centrifuge
Vacuum dryer
Shell (by-product)
Hydrocyclone
Drain cyclone water (by-product)
Sludge (by-product)
Oil
Kernel Dryer
Kernels

Figure 1.

the following five main stages:-

(i) Steam sterilisation of fresh fruit bunches (FFB).
(ii) Fruit-stalk separation by stripping.
(iii) Digestion of stripped fruits.
(iv) Oil expression by screw press.
(v) Oil clarification.

Milling FFB is therefore essentially a physical and mechanical process. The oil is expressed from the mesocarp of the fruit by a screw press. No chemical is used. However, large volumes of water are required for boiler feedwater and process water. The treatment indicated in *Figure 1* are also the processes generating by-products. A detailed description of the by-products is given below.

BY-PRODUCT UTILISATION

Fibre and Shell

For every tonne of crude palm produced, a palm oil mill generates 0.70 and 0.35 tonne of fibre and shell respectively. Thus, for an average mill producing 6 tonnes of crude oil per hour, about 4.2 and 2.1 tonnes of fibre and shell are generated respectively. These by-products, if not utilised and managed properly, will impose a disposal problem to the palm oil mill concerned.

It is also fortunate that the palm oil industry is bestowed with such vast amounts of these by-products of high calorific value *(Table 1)* which can be burnt directly without further treatment. All the palm oil mills in Malaysia use the fibre and shell as boiler fuel to produce steam to generate electricity for the operation. The fibre and shell together can supply more than enough electricity for the mill as only about 100 kwh of electrical energy is required to produce one tonne of palm oil. The main disadvantage of burning these solid biomass is the emission of dark smoke when the combustion is incomplete due to overfeeding of the furnance. This has been overcome to a large extent by automating the fuel feeding system. The beneficial use of the biomass also gets rid of the bulky materials which would otherwise contribute to environmental pollution if disposed off indiscriminately.

There is an intensive research to utilise these biomass for value-added products. The results have been encouraging but unless and until they are commercialised and the revenue generated can offset the alternative fuel or energy cost for the palm oil mill, the by-products will continue to be used as boiler fuel. It has commonly been taken for granted that energy is free in the palm oil mills and this has undoubtedly contributed greatly to the success of the industry.

Empty Fruit Bunches

Apart from fibre and shell, empty fruit bunches (EFB) are another valuable biomass by-product which has attracted much attention lately. About 1.1 tonnes of EFB are generated for every tonne of oil produced. EFB is traditionally incinerated for its ash which contains high plant nutrients, particularly potassium *(Table 2)*.

The ash, besides being a valuable source of potassium, is also high in alkalinity and useful for oil palm on alluvial soils, particularly acid sulphate and peat.

The problem associated with incinerating EFB is the emission of 'white smoke' which is, merely, water vapour with some fly ash carried over. However, it is unsightly and the practice is discouraged by the

TABLE 2. COMPOSITION OF EMPTY BUNCH ASH (% dry basis)

Potassium (K_2O)	Phosphorus (P_2O_5)	Magnesium (MgO)	Calcium (CaO)
41.4	3.7	5.8	4.9

Source: Toh *et al.* (1981)

TABLE 3. COMPOSITION OF EMPTY FRUIT BUNCH

Parameter		Dry Matter Basis				Fresh Wt.Basis*
		Range			Mean	(Mean)
Ash	(%)	4.80	–	8.70	6.30	2.52
Oil	(%)	8.10	–	9.40	8.90	3.65
Carbon (C)	(%)	42.00	–	43.00	42.80	17.12
Nitrogen (N)	(%)	0.65	–	0.94	0.80	0.32
Phosphorus (P_2O_5)	(%)	0.18	–	0.27	0.22	0.09
Potassium (K_2O)	(%)	2.00	–	3.90	2.90	1.16
Magnesium (MgO)	(%)	0.25	–	0.40	0.30	0.12
Calcium (CaO)	(%)	0.15	–	0.48	0.25	0.10
Boron (B)	(ppm)	9.00	–	11.00	10.00	4.00
Copper (Cu)	(ppm)	22.00	–	25.00	23.00	9.00
Zinc (Zn)	(ppm)	49.00	–	55.00	51.00	20.00
Iron (Fe)	(ppm)	310.00	–	595.00	473.00	189.00
Manganese (Mn)	(ppm)	26.00	–	71.00	48.00	19.00
Carbon/Nitrogen (C/N) ratio			–		54.00	54.00

* Moisture content 60%-65%

Source: Gurmit Singh *et al.* (1989)

Department of Environment (DOE) and such incineration is not allowed for new establishment. A new use for this bulky biomass in an environmentally and socially acceptable manner has to be found.

However, EFB is a good source of organic matter and plant nutrients *(Table 3)* and it is increasingly being recycled back to the plantation as a mulch so that it does not present a problem with disposal. In fact, the practice has long term benefits as the mulching improves palm growth and increases the yield (Gurmit Singh *et al.*, 1989; Lim and Chan, 1989). Mulching also conserves soil moisture, increases the soil pH and markedly reduces soil erosion.

EFB is also a potential source of energy, but as yet little exploited. This is partly because there is already enough energy from the fibre and shell. Due to its physical nature and high moisture content, it has to be pretreated to reduce its bulkiness and bring its moisture content to below 50% in order to render it more easily combustible (Gurmit Singh *et al.*, 1989; Chua, 1991).

Palm Oil Mill Effluent

Large quantities of water are required in palm oil milling – about five to seven tonnes to produce one tonne of palm oil. Two to three tonnes are used as boiler feedwater and the remainder as process water for dilution, washing, *etc.* About half the water used ends up as palm oil mill effluent (POME) and the rest lost as steam through sterilizer exhaust, leakages, *etc.*

POME is a mixture of steriliser condensate, separator sludge and hydrocyclone wastewater *(Figure 1).* Fresh POME is a colloidal suspension of 95%-96% water, 0.6%-0.7% oil and 4%-5% total solids including 2%-4% suspended solids which are mainly debris from palm fruit mesocarp. Other characteristics are shown in *Table 4.*

POME is highly polluting in terms of its BOD which is about 100 times that of domestic sewage.

In the early history of the industry (1960 -1970), when the number of mills was small, POME was conveniently discharged into nearby rivers to be diluted by the volume of river water. However, with the rapid

TABLE 4. CHARACTERISTICS OF PALM OIL MILL EFFLUENT

Parameter	Concentration*	Element	Concentration*
pH	4.7	Phosphorus	180
O&G	4 000	Potassium	2 270
BOD	25 000	Magnesium	615
COD	50 000	Calcium	439
TS	40 500	Boron	7.6
SS	18 000	Iron	46.5
TVS	34 000	Manganese	2.0
AN	35	Copper	0.89
TN	750	Zinc	2.3

* All parameters in mg/L except pH

O&G – Oil and Grease
TS – Total Solids
SS – Suspended Solids
AN – Ammoniacal Nitrogen
BOD – Biochemical Oxygen Demand
COD – Chemical Oxygen Demand
TVS – Total Volatile Solids
TN – Total Nitrogen

expansion of the palm oil industry coupled with increased environmental awareness, the industry has had to treat its effluent to an acceptable level before discharge. Realising the potential pollution that can be caused by the industry, the Government has enacted the Environment Quality Regulations for the palm oil industry in 1978. The DOE has set the discharge standards for POME in *Table 5.*

Treatment Technology for POME

Over the last two decades, various treatment and disposal methods have been successfully developed and employed by palm oil mills to treat their POME. Conventional biological treatments of anaerobic and aerobic or facultative digestion are used. If well operated and maintained, the processes are able to treat POME to the discharge standards stipulated by the DOE *(Table 5).*

Biological treatment systems need proper maintenance and monitoring as the processes rely solely on microorganisms to break down the pollutants. The microorganisms are very sensitive to changes in the environment and thus great care has to be taken to ensure that a conducive environment is maintained for the microorganisms to thrive in. It requires skilful attention and commitment. However, wastewater treatment has always been considered a burden to the industry and not part of the production process, let alone a profit centre. Undoubtedly, it gets the lowest priority in the operation and maintenance budget. As a result, not all the mills can meet the DOE discharge limits all the time.

TABLE 5. PARAMETER LIMITS FOR WATERCOURSE DISCHARGE OF POME

*Biochemical Oxygen Demand (BOD) (mg/L)	100
Suspended Solids (mg/L)	400
Oil and Grease (mg/L)	50
Ammoniacal Nitrogen (mg/L)	150
Total Nitrogen (mg/L)	200
pH	5-9

* BOD – sample incubated for 3 days at 30°C

As the country is fully committed to environmental protection, it is expected that more stringent discharge standards will be imposed. In fact, in some sensitive areas such as water catchments, the DOE imposes a 20mg/L BOD or zero discharge requirement. This has posed a tremendous challenge to the industry to come up with a fool-proof clean technology.

Many improved biological systems (both anaerobic and aerobic) have been evaluated. These include thermophilic anaerobic contact, anaerobic filter, hybrid anaerobic reactor upflow, anaerobic sludge blanket reactor, and a train of aerobic systems. However, none of them can guarantee a discharge standard of 20mg/L BOD. Therefore, the industry is understandably keen to invest in them.

It is believed that it will be very costly to achieve a BOD discharge of 20mg/L. This would render the industry non-competitive unless there is some form of economic return (however low).

Land Application of Digester POME

POME contains very high levels of nutrients (Kanagaratnam *et al.*, 19981; Lim, 1987; Lim *et al.*, 1984; Mohd. Hashim Tajudin and Zin Z Z, 1984; Mohd. Tayeb Dolmat *et al.*, 1987; Quah *et al.*, 1982; Yeow and Gurmit Singh, 1983) *(Table 6).*

Land application of POME is allowed with approval from the DOE if the BOD is less than 5000mg/L. It is, however, necessary to apply the effluent in a proper manner safe to the environment. POME application is beneficial to the soil and crop. Crop yield increases of 10% to 24% have been reported (Tam *et al.*, 1982; Lim *et al.*, 1984; Lim, 1987) due to increases in soil nutrients and moisture level. In many cases, the nutrients from POME can totally replaced the mineral fertilisers needed. Thus, tremendous savings in fertilisers costs have been realised. Water quality in the areas of application is not significantly affected (Mohd. Tayeb Dolmat *et al.*, 1987).

This positive development has resulted in a paradigm shift in the management of POME. It has changed the concept of treatment and disposal to beneficial utilisation. The practice is strongly recommended as it meets the zero discharge requirement and also generates extra income through increased crop yields and savings in fertiliser. Land application of POME has become standard practice for most mills with plantations nearby. The practice is viable for about 30% of the 290 palm oil mills in the country. The rest of the mills without nearby plantations will have to look for an alternative affordable clean technology to meet the zero waste requirement.

TABLE 6. TYPES OF POME AND THEIR CHEMICAL COMPOSITIONS (mg/L)

POME	BOD	N	P	K	Mg
Raw	25 000	948	154	1 958	345
Digested (Anaerobic)					
Stirred tank	1 300	900	120	1 800	300
Supernatant	450	450	70	1 200	280
Supernatant 10% slurry	191	320	42	1 495	258
Bottom slurry	1 000-3 000	3 552	1 180	2 387	1 509
Digested (Aerobic)					
Supernatant	100	52	12	2 300	539
Bottom slurry	150-300	1 495	461	2 378	1 004

Source: Kanagaratnam *et al.* (1981); Lim *et al.* (1983); Yeow and Gurmit Singh (1983)

ZERO WASTE TECHNOLOGY

As discussed earlier, an elaborate treatment system is required to reduce the BOD of the POME to an acceptable level for discharge into watercourses. Due to various reasons, not many palm oil mills treating POME are able to meet the DOE discharge standards. The mills concerned are eager for an affordable alternative to solve the problem. The best option is to recover the water for reuse and add value to the solids concentrate obtained. This means that no waste is discharged from the mill. This can be achieved through evaporation.

Application of Evaporation Technology to Process POME

Evaporation is one of the most widely used unit operation in the chemical process industries. It is generally applied to remove water from aqueous solutions in a broad range of processing applications including processing of wastewater:-

- Concentration of dairy product (Boumann *et al.*, 1988).
- Concentration of gelatine (EC DEMO No. 82, 1990).
- Concentration of glycerine (Amir Kinkhabwala, 1984).
- Concentration of by-product hardboard plant wastewater (Fredrickson, 1984).
- Desalination of brackish or seawaters (Yundt and Rhinesmith, 1981).
- Production of natural rubber serum concentrate (Hanif Junit, 1994).

In Malaysia, evaporation has been commercially used to produce natural rubber serum concentrate from wastewater generated by latex factories (Hanif Junit,1994). A similar technology was evaluated for process POME (Ma, 1994). A process flow diagram of the pilot plant is shown in *Figure 2.*

POME containing 3%-4% total solids was used as feed for the evaporation process. A concentrate of 20%-30% solids content was produced. The solids concentrate contains high plant nutrients *(Table 7)* and is a good feed material for making fertiliser.

About 85% of the water in the POME can be recovered as distillate. The quality of distillate is good and can be reused as boiler feedwater or process water with minimal chemical treatment *(Table 8).* The quantity recovered is sufficient to meet the boiler feedwater requirement. This would offset water intake from the river or other sources. The cost for water treatment is reduced accordingly. More importantly, there is no liquid discharge from the mill as it is a completely closed-loop system.

TABLE 7. NUTRIENT ANALYSIS OF PALM OIL MILL EFFLUENT CONCENTRATE

	Wet Basis (%)	Dry Basis (%)
Total Nitrogen	0.41	2.07
Ammoniacal Nitrogen	0.03	0.15
Total Phosphorus (P_2O_5)	0.19	0.96
Water Soluble P_2O_5	0.15	0.76
Total Potassium (K_2O)	1.29	6.51
Total Calcium (CaO)	0.023	0.12
Total Magnesium (MgO)	0.396	2.00
Total Manganese (MnO)	0.003	0.015
Total Iron	0.007	0.035
Total Sodium	0.004	0.020
Moisture	80.0	

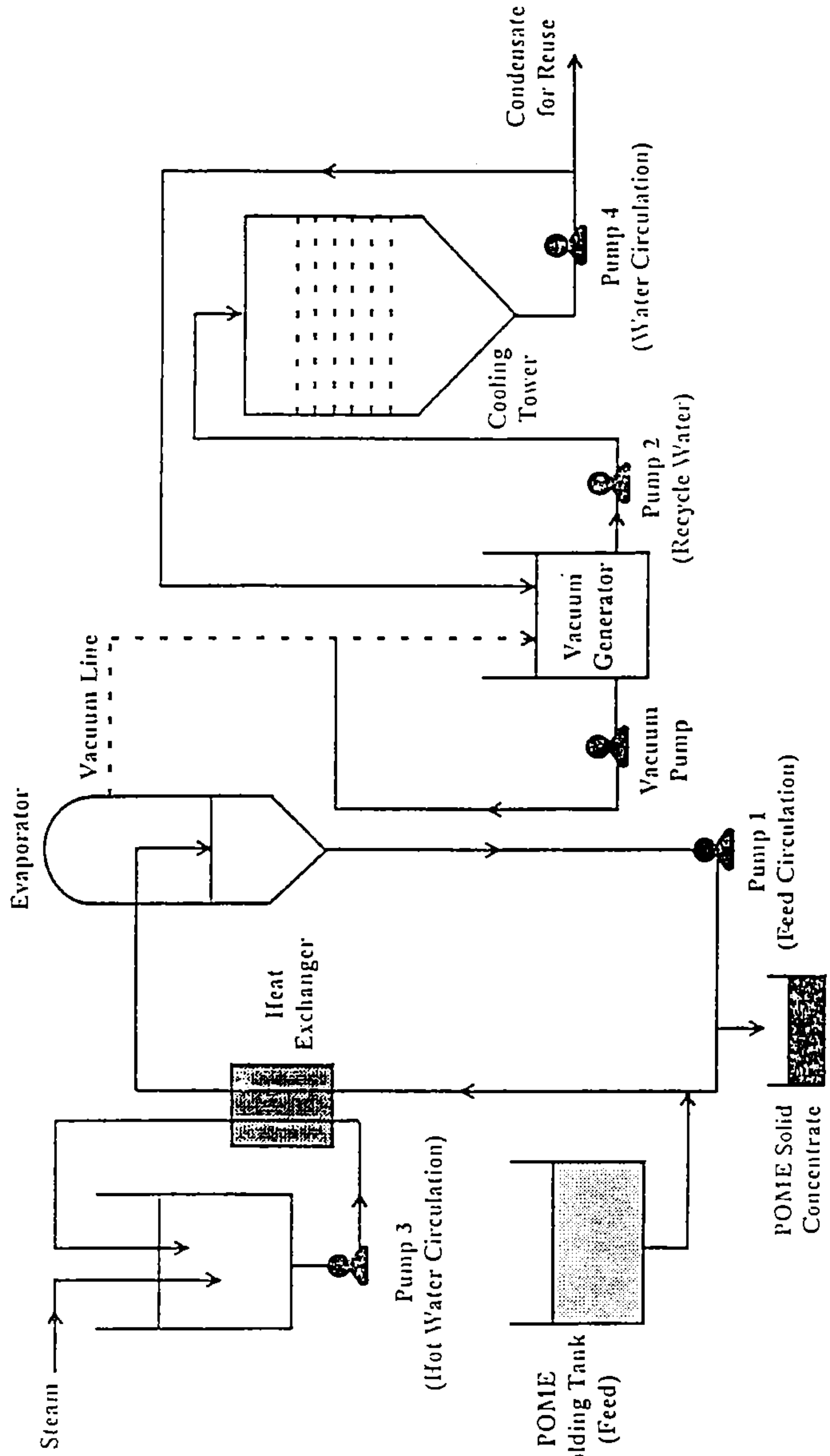
Condensate for Reuse
Pump 4 (Water Circulation)
Cooling Tower
Pump 2 (Recycle Water)
Vacuum Generator
Vacuum Line
Vacuum Pump
Evaporator
Pump 1 (Feed Circulation)
Heat Exchanger
POME Solid Concentrate
Pump 3 (Hot Water Circulation)
Steam
POME Holding Tank (Feed)

Figure 2.

TABLE 8. QUALITY OF DISTILLATE

Appearance	Clear to slight turbid
pH	5-6
Chemical Oxygen Demand (mg/L)	100-600
Biochemical Oxygen Demand (mg/L)	20-150
Total Solid (mg/L)	150
Suspended Solid (mg/L)	10
Oil and Grease (mg/L)	10
Ammoniacal Nitrogen (mg/L)	6
Total Nitrogen (mg/L)	20
Iron (mg/L)	Not detectable
Phosphorus (mg/L)	Not detectable

Energy Demand for the Evaporation Process

Energy requirement is the major consideration in any evaporation process. It is envisaged that the heat (from steam) and electrical energy required can be provided by the mill's energy production system. Under standard conditions, the specific energy consumption is taken as one (*i.e.* one kg of steam per kg water evaporated). In recent years, significant advances have taken place in evaporation technology to reduce the energy consumption. A modern evaporator now has a specific energy consumption of 0.1. This is achieved by increasing the number of evaporators and by efficient thermal vapour recompression. As fresh POME from the mill is hot (80°C-90°C), little heating in fact is required.

CONCLUSIONS

From the above discussion, it is obvious that the concept of zero-waste is possible for the oil palm industry and several options are available to achieve it. Land application is viable for mills with nearby plantations. Evaporation is a viable option for mills without plantations. While the technologies can yet be further improved, it can already be used now with surplus energy, readily available. By using evaporation, POME can be processed to produce high quality water (distillate) and solids concentrate. The water can be reused as boiler feedwater or process water with minimal chemical treatment. The solids concentrate can be made into fertiliser or animal feed. It is a fool-proof technology.

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