TABLE II.

Typical Specifications of Activated Carbon

	Min	Max
Iodine number	1200	
Carbon tetrachloride (wt%)	60	
Ash (%)		4.0
Moisture (%)		3.0
Hardness Number	98	
Apparent Density	0.44	
Magnetics		0.6
Sulfur		0.05

ity of air and water pollution problem would be an enormous mistake, for these ecological problems generated by modern technological advances are expected to increase in the years to come, probably reaching several times the present level by the end of this century. If serious research and development in the downstream application could be undertaken, however, solutions to these ecological problems might lie in the usage of activated carbon.

Most industrialized countries are continually seeking effective means to control environmental pollution. Merging private enterprise's research and development with governmental control planning has already been effected to preserve the harmony between man and nature. Ecologists have expressed their fears and doubts of the continual survival of humankind if air and water pollution continue to be left unchecked.

Now that the world is at the threshold of developing efficient pollution control devices, the Asian-Pacific region, as the primary producer of coconut products, should take advantage of this golden opportunity by further nurturing the activated carbon industry in which it has a comparative advantage. The region undoubtedly has the raw material; what is needed is the technical knowledge to maximize its utility. This can be done through research and development in the areas of solvent recovery in industrial applications, ore purification and the improvement of current devices to counteract both air and water pollution.

CONCLUSION

It can be noted that the unwelcome side effects of modern technology can provide lucrative economic opportunities to the once ignored coconut byproduct, shell. Coconut-shell charcoal has aptly demonstrated its unrivalled position as the best source of raw material for activated carbon in certain applications, specifically in the gas/vapor phase pollution-control devices.

With this development, one can readily assume that the world-wide market for coconut-shell activated carbon will grow along with the industrial growth of the countries of the world who are concerned with pollution and its ill effects. I hope that the Asian-Pacific Region will be ready to service this increasing demand and will not forego the bright opportunities brought about by world-wide industrial proliferation.

Pollution Control in Palm Oil Mills in Malaysia

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ABSTRACT

Pollution prevention approaches are being adopted by more and more mills. Digested POME increasingly is being used successfully as a fertilizer/soil conditioner, resulting in significant savings in imported fertilizers. Studies also have shown that energy can be obtained from biogas generated from anaerobic digestion of POME; in fact, electricity from POME has become a reality. These technological developments and the increasing awareness of the economic value of POME have made it a valuable, renewable resource.

INTRODUCTION

In Malaysia, with a land area of about 14 million hectares, there are more than 1.2 million hectares in oil palm cultivation. Presently, there are 210 palm oil mills which are capable of processing a total of 6743 tons of fresh fruit bunches (FFB) per hour. There are another 47 mills under planning or construction which could process another 1134 tons of FFB/hr. In 1983, Malaysia produced 3.01 million tons of crude palm oil, making it the world's largest palm oil producer with more than 60% of the world's total output.

Over the last decade, the palm oil industry has become one of the largest revenue earners and has contributed much toward Malaysia's development and improved standard of living. However, the palm oil mills also have generated enormous amounts of highly polluting effluent (Table I), which amounted to more than 7.5 million M^3 in 1983. It has been singled out as the chief contributor to Malaysia's environmental pollution.

TABLE I

Characteristics of Palm Oil Effluent and Department of Environmental Standards

Parameters[a]	POME	Doe standards
pH	4.5	5.0-9.0
BOD	25,000	100 (50)[b]
Suspended solids	19,000	400
Total nitrogen	770	200[c]
Ammoniacal nitrogen	35	100[c]
Oil and grease	8,000	50
Temperature (C)	80-90	45 C

[a]All parameters in mg/l except pH and temperature.
[b]This additional limit is the arithmetic mean value determined on the basis of a minimum of 4 samples taken at least once a week for 4 consecutive weeks.
[c]Value on filtered sample.

The palm oil mills traditionally have discharged their effluents into rivers leading to the seas. They relied solely on nature to absorb large quantities of waste products. With the rapid expansion of the industry and the public's increased awareness of environmental pollution, the industry is obliged both socially and aesthetically to treat its effluent before it is discharged. The Government also has responded by enacting the environmental laws in 1976 to control the pollution caused by the palm oil industry. The laws require the palm oil mill effluent (POME) to be treated to a required standard before it can be discharged (Table I).

Production, Properties of Palm Oil Mill Effluent

A schematic flow diagram of the palm oil extraction process is shown in Figure 1. It consists of 5 main stages:

- Steam sterilization of fresh fruit bunches.
- Fruit-stalk separation by stripping.
- Digestion of stripped fruits.
- Oil extraction by means of screw presses.
- Clarification where crude palm oil is separated from the residue aqueous liquor and debris.

Liquid effluent is generated mainly from the sterilization and clarification processes in which large amounts of steam and/or hot water are used. Another waste stream originates from the hydrocyclone operation in which the broken shell is separated from the kernels. Under proper operations and management, the amounts of effluent generated from sterilization, clarification and hydrocyclone are respectively 0.9 M^3, 1.5 M^3 and 1.0 M^3 per ton of oil produced, i.e. about 2.5 M^3 of POME per ton of oil produced (1).

POME, when fresh, is a thick brownish slurry. It is acidic and contains very high organic matters as indicated by its high biological oxygen demand (BOD_3, incubated at 30 C for 3 days). It is 100 times as polluting as domestic sewage. The suspended solids in the slurry are mainly cellulose matter mixed with some residue oil. The effluent is non-toxic as no chemical is added to the oil extraction process.

TREATMENT OF PALM OIL MILL EFFLUENT

The survey made by Ma et al. (2) has indicated there are 5 different treatment systems adopted by the industry. Three of them are being monitored by PORIM and are discussed in this paper.

Ponding System

This is the most popular method for treatment of POME in Malaysia. More than 85% of the mills have adopted the ponding system.

The system consists of essentially a number of ponds for different purposes. A typical ponding system is shown in Figure 2, which uses a two-phase operation, i.e. the acidification phase is separated from the methanogenic phase as shown. Chan and Chooi (3) and Chooi (4) have reported that the system has proven reliable, stable and capable of producing the final discharge with a BOD of about 100 mg/l. The problem of sludge build-up in the anaerobic pond is solved by regular desludging by means of a submersible slurry pump. The sludge is dried in sand beds built beside the pond.

A ponding system is cheap to construct, but it requires a large land area. The anaerobic pond is usually 5 M to 7 M deep, and the facultative pond is about 1.5 M deep. The hydraulic retention times for the anaerobic and facultative ponds are repectively 45 days and 16 days. Ponding system is normally operated at low rate, with organic loading of 0.2 to 0.35 kg BOD/m^3. Because of the size and configuration of the ponds, they are quite difficult to control and

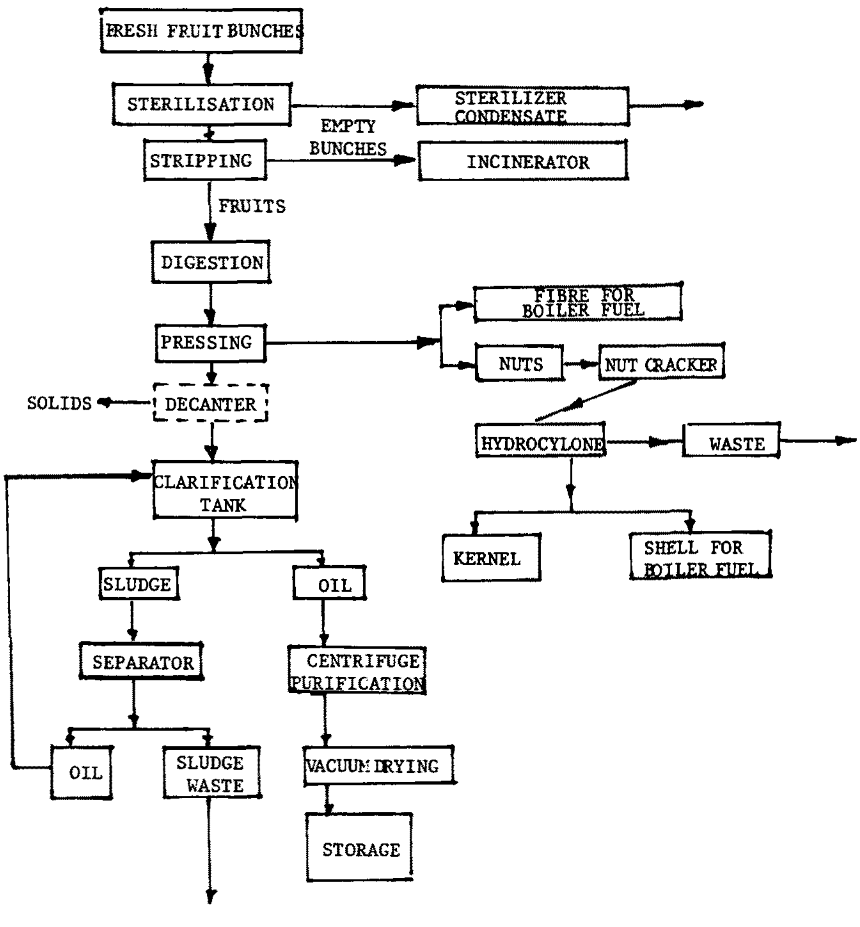

FIG. 1. Palm oil extraction process.

monitor. Furthermore, mixing (by the biogas evolved) is hardly adequate. It is not uncommon to find dead spots or short circuiting in the pond system. Islands of solid can be seen floating in the anaerobic ponds. Undoubtedly, it would be very labor intensive to maintain the ponds.

Energy required to operate the ponding system is minimum. It is required only to run the pumps. For a 30 ton FFB/hr mill, the energy required is about 20 KW (3).

The performance of the ponding system is indicated by the monitoring results shown in Table II, which indicates that it reduces BOD more than 99%.

The capital cost for the ponding system depends on the capacity of the mill. For a 30-ton FFB/hr mill the capital cost is in the region of M$ 330,000.00 excluding land cost. There is very little return (if any) from the sales of dried sludge cake which has good fertilizer value.

Tank Digester with Biogas Recovery and Land Application

This integrated system of POME treatment is adopted by the Sime Darby Plantations. Tank digesters with individual capacities from 1,500m^3 to 4,200m^3 have been constructed (5). The digesters are operated as a conventional high rate system with loading of 4.8 kg volatile solids (VS)/m^3 day. The hydraulic retention time is about 10 days operating at a temperature range of 42 C - 50 C. Good mixing is ensured by recycling the biogas through an emitter and a draught tube, as shown in Figure 3.

The digesters in some of the mills have been operated for more than 5 years and very consistent performance is observed. Table III shows the average performance of the digester. About 90% removal of BOD is achieved.

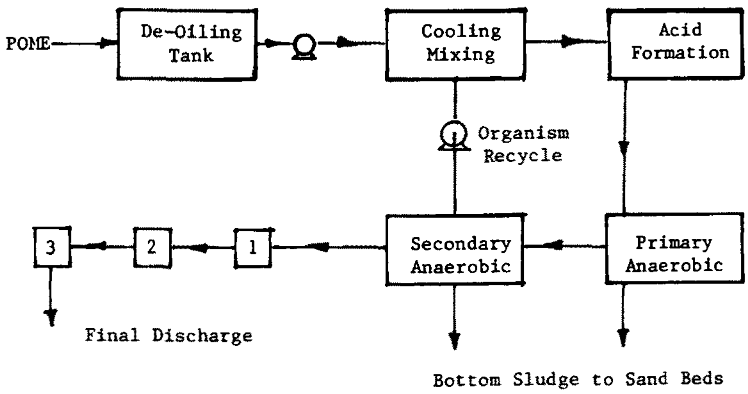

FIG. 2. Ponding system for POME treatment.

TABLE II

Average Results of Pond System

Parameter[a]	A	B	C	D	E	F
pH	5.4	4.9	8.2	9.0	8.3	9.3
BOD	30,000	24,000	670	400	120	100
Suspended solids	34,000	21,000	500	300	280	270
Total nitrogen	950	900	500	600	100	90
Ammoniacal nitrogen	40	60	300	220	30	30

[a]All except pH in mg/l.
A = raw POME; B = acid pond liquor; C = anaerobic liquor 1; D = anaerobic liquor 2; E = facultative liquor, F = final discharge.

TABLE III

Digester Performance (10 days retention)

Parameters[a]	Raw POME	Digester liquor
pH	3.8	7.3
BOD_3	30,000	3,000
TVS	48,000	14,000
TS	60,000	30,000
N	1,000	900
P	290	220
K	2,280	1,800
Mg	580	460
Ca	560	480

[a]All in mg/l except pH.
Source: Lim et al. (5).

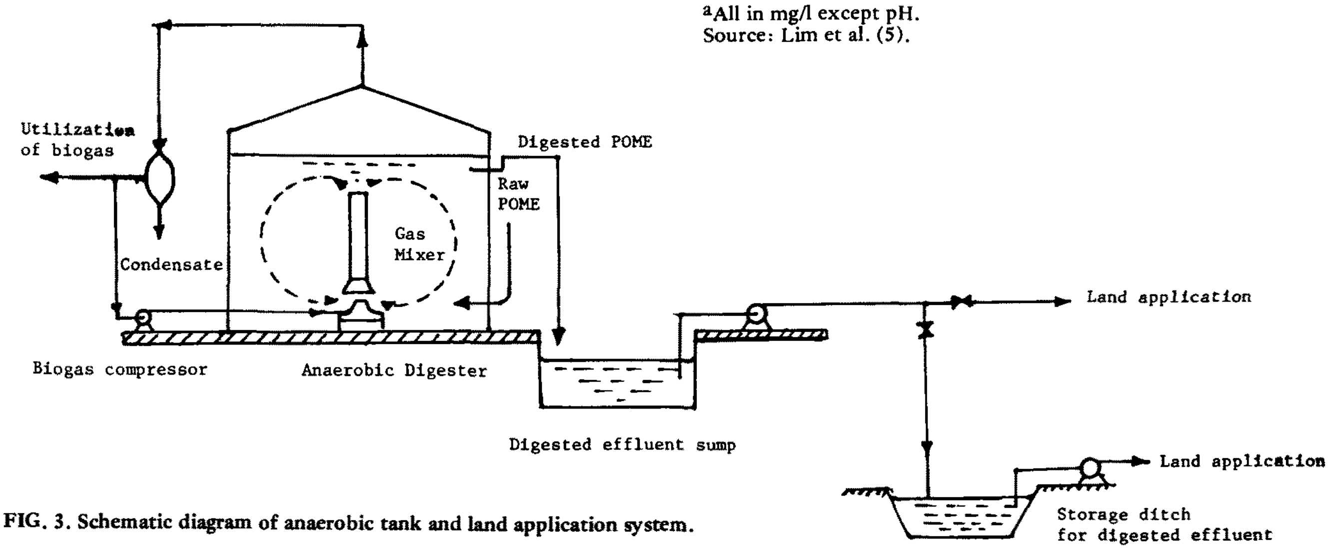

FIG. 3. Schematic diagram of anaerobic tank and land application system.

Biogas Production and Utilization

A valuable gaseous product—biogas—is generated by the digestion of POME under anaerobic conditions. About 0.59 m^3/(kg VS added) of biogas is produced. For a 60-ton FFB/hr palm oil mill operating for 20 hr/day, about 20,000 m^3/d of biogas is obtainable. The biogas contains about 65% methane (CH_4), 35% carbon dioxide (CO_2) and less than 2,000 ppm of hydrogen sulphide (H_2S). It has a calorific value of about 5,300 kcal/m^3.

The biogas thus produced can easily be used for heat and electricity. The biogas is being used to produce heat for drying rubber (6). Approximately 7m^3 biogas is required to replace 4.54 liters of diesel fuel in this application, and a saving of M$ 49,000/yr on diesel fuel is realized. This is very attractive if the rubber factory is in the vicinity of the palm oil mill.

The biogas also is being used to generate electricity. The H_2S has to be reduced to below 1000 ppm if a gas engine is used. In one of the Sime Darby palm oil mills, the gas/electricity generating set has been operating satisfactorily for more than 9,500 hr (5).

Land Applications of Digested POME

Land application of POME is allowed by the Department of Environment (DOE), provided the BOD is reduced to below 5,000 mg/l; otherwise prior permission has to be obtained from the Director General of DOE. As shown in Table III, the POME (both raw and digested) contains quite a substantial amount of plant nutrients. Its application to land has been shown to be beneficial to crops, as well as the soil properties (5,7,8,9,10). Crop yield increases in the order of 10% to 24% have been reported. The yield improvement was attributed to the increased soil nutrients provided by POME. The increased soil moisture status due to direct irrigation and enhanced soil water retention characteristics also played a part. Yeow (11) estimated that the fertilizer equivalent of POME produced annually amounts to M$

TABLE IV

Economic Analysis for a Totally Integrated Scheme for a 60-Ton FFB/Hr Mill

Items	Digester	Gas engine	Land application (flatbeds)	Totally integrated system
1. Total capital cost	M$1,367,000	M$1,041,000	M$300,000	M$3,308,000
Capital cost/yr	227,830	300,850	60,000	538,680
2. Operating cost/yr	120,603	159,160	39,160	318,923
3. Revenue/yr		1,228,220	146,000	1,374,200
4. Net revenue/yr		1,069,040	106,840	1,055,277
5. Payback (yrs)		1.5	2.8	3.1

The evaluation assumes 70% mill utilization rate.
Depreciation for digesters, gas engine and land application schemes are taken to be 15, 12 and 10 yr respectively, all on a straight line basis.
Interest on capital investment is taken as 10%.
Electricity generated from biogas is taken to be 890 KW over 20 hr per day for 300 days per year.
Electricity is valued at M$ 0.23 per unit.
Land application on 200 hectares @ M$ 450 per ha.
10% increase in crop yield is taken into consideration.

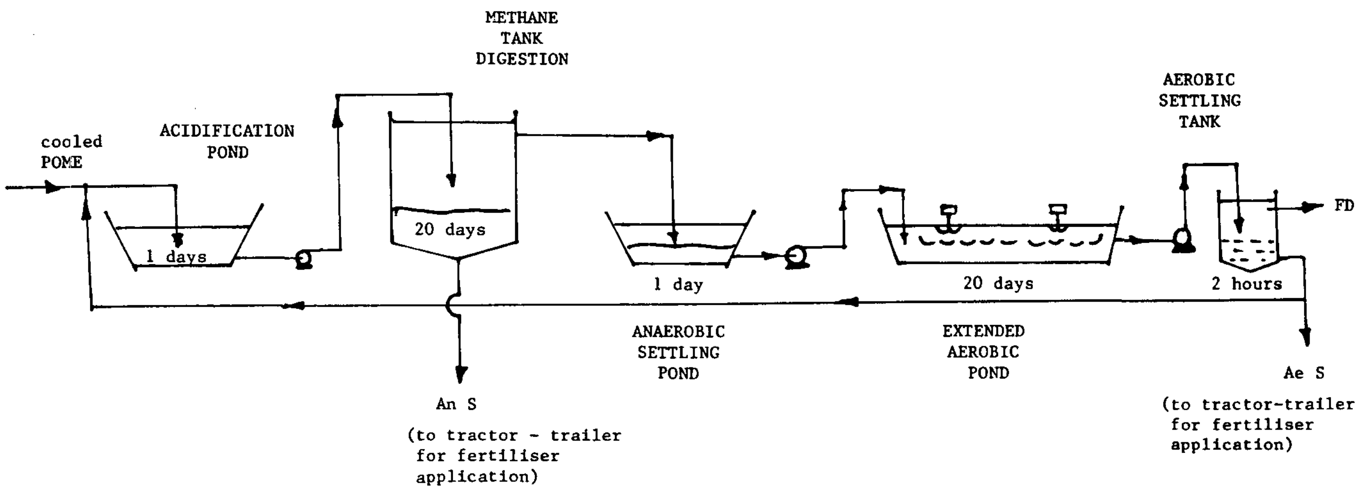

FIG. 4. Anaerobic contact and aeration process. FD = final aerobic discharge; An S = anaerobic sludge, and Ae S = aerobic sludge.

52 million. Zin et al. (12) reported that the water quality in the applied areas was not contaminated as far as BOD was concerned.

Economic Evaluation of a Totally Integrated Scheme

Undoubtedly the initial capital investment in an integrated system of this nature (with anaerobic digester, electricity generation and land application) is very high. However, the high capital cost can be offset by the potential revenue generated by such a system. Quah et al. (13) showed that the payback period for an investment of M$ 3.3 million is about 3.1 years (Table IV).

Tank Digester and Extended Aeration

In this system, the POME is treated in a primary unstirred 2-phase anaerobic contact digestion process followed by extended aeration in a pond as shown in Figure 4. The hydraulic retention in each stage is also shown. The organic loading is in the range of 0.8-1.0 kg BOD/m^3. Table V shows the overall performance of such a system. As observed in the earlier systems, very good removal of BOD is effected. About 93% of the BOD is removed in the anaerobic stage, and an overall BOD removal efficiency is more than 99%. The extended aeration also is very efficient in the removal of nitrogen, particularly the ammoniacal nitrogen. However, the nitrogen may have been converted to nitrate (nitrification) or driven off the system as ammonia gas. Undoubtedly, the aeration system is very energy intensive as air (oxygen) is transferred into the system by mechanical aerators. The mechanical aerators used in such a system require an energy input of about 33 KW (14).

Desludging of the tank digester solids is done intermittently. The solids are carted away for land application.

The initial capital investment cost of such a system for a 20-ton FFB/hr mill is about M$ 600,000, and the operation cost varies from M$ 0.30 to M$ 0.60 per ton of FFB processed (15).

TABLE V

Average Results of Tank Digester and Aerated System

Parameter[a]	Raw POME	Anaerobic liquor	Aerobic liquor	Final discharge
pH	4.7	7.5	8.5	8.6
BOD_3	30,000	2,100	380	80
Suspended solids	27,000	14,000	6,200	500
Total nitrogen	870	1,300	560	100
Ammoniacal nitrogen	50	200	10	0

[a]All except pH in mg/l.

TABLE VI

Average Results of Decanter-Drier-Pond System

Parameter[a]	Raw POME[b]	Final discharge
pH	5.4	8.4
BOD_3	27,000	60
Suspended solids	2,300	130
Total nitrogen	760	130
Ammoniacal nitrogen	50	80

[a]All except pH in mg/l.

[b]Mainly sterilizer condensate.

Decanter-Dryer and Ponding System

A pollution prevention approach is adopted in developing this sytem. A decanter is incorporated between the pressing and clarification station of the palm oil extraction process shown in Figure 1. The oily mixture coming from the pressing station is passed through the decanter, where the solid is separated from the oily liquor. The oily liquor is charged to the conventional clarifier for oil recovery and the solid is dried in a rotary dryer using the heat discharged from the boiler exhaust. It is reported that such a system has successfully eliminated effluent production from the clarification station which amounts to about 75% of the total effluent produced from a conventional process (16). The effluents from sterilization and hydrocyclone station are treated in an anaerobic pond. The effluent from such a system contains mainly dissolved organic solids and is much easier to treat as shown in Table VI. More than 99% removal of BOD is achieved.

The solids (palm oil meal) have been shown to be a good conditioner/fertilizer (9,17) as well as animal feed (18-23).

The cost for such a system is about M$ 900,000 (16). It is claimed that there is a definite return on the investment from the sale of the palm oil meal which could fetch not less than M$ 75/ton.

The other advantage of this system is that the air pollution from the boiler chimney is reduced to a minimum.

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