MALAYSIAN AGRICULTURAL RESEARCH AND DEVELOPMENT INSTITUTE

MARDI

THE TREATMENT OF PALM OIL PROCESSING WASTES

DECEMBER 1970

J. D. & D. M. WATSON, FF.I.C.E.

67 Tufton Street
Westminster
London SW1

M.S.A. Building
77 Robinson Road
Singapore 1

I N D E X

Section	Subject	Page

PARTNERS
H. ROY OAKLEY, M.Sc., C.Eng., F.I.C.E., A.M.I.W.E., F.ASCE.
TERENCE CRIPPS, B.Sc., C.Eng., F.I.C.E.
HUGH T. HALE, T.D., B.Sc., C.Eng., F.I.C.E., M.I.W.E.
GRAHAM S. G. GOODE, B.Sc., A.C.G.I., C.Eng., F.I.C.E., A.M.I.W.E.
JOHN R. STEWART, M.B.E., B.Sc., C.Eng., F.I.C.E., [illegible].W.E., F.ASCE
JOHN F. BATES, B.Sc., C.Eng., M.I.C.E.
J. R. PRESTON, C.Eng., M.I.C.E.

CONSULTANTS
DAVID MOWAT WATSON, B.Sc., C.Eng., F.I.C.E., HON. F.R.S.H., M.I.W.E.
HUMPHREY D. MANNING, B.Sc., C.Eng., F.I.C.E., F.R.S.H.
PROFESSOR PETER C. G. ISAAC, B.Sc., C.Eng., S.M., F.I.C.E.

ASSOCIATES
D. H. HUGHES, B.Sc., C.Eng., M.I.C.E.
H. G. HADEN, B.Sc., C.Eng., F.I.C.E., A.M.I.W.E.
A. F. SHORT, C.Eng., F.I.C.E., A.M.I.W.E.
J. [illegible]. JOSLIN
J. M. BIDWICK, M.I.W.P.C.

SECRETARY
L. V. WATSON, C.Eng., F.I.C.E.

J. D. & D. M. WATSON
Chartered Civil Engineers

67, TUFTON STREET
WESTMINSTER
S.W.1

TELEPHONES
01-222 1584-7
& 1525-8

OUR REF.

YOUR REF.

A.H. Moseman, Esq.,
Director,
Malaysian Agricultural Research and Development Institute,
Jalan Swettenham,
Kuala Lumpur,
Malaysia.

Dear Sir,

Palm Oil Processing Wastes

We refer to your letter of instruction of 28th August 1970 and are now pleased to submit our Report on Palm Oil Processing Wastes. We hope that this Report fulfills our terms of reference to your satisfaction. We shall be pleased to answer such queries as may arise and we would be glad to advise and expand on experimental needs or make detailed proposals for individual mills should you wish.

For your convenience we summarise below our recommendations and conclusions.

1. SUMMARY OF RECOMMENDATIONS AND CONCLUSIONS

1.1 This Report is a preliminary review, dwelling on the problems of palm oil waste treatment and disposal in broad terms only.

1.2 We limit detailed consideration to the steriliser condensate and the clarification sludge and discuss the extent of the problems created by these wastes when discharged from a generalised mill processing 10 ton f.f.b./hour.

1.3 We estimate that the wastes from a single 10 ton f.f.b./hour mill are equivalent in terms of pollution to the domestic sewage from a town of over 51,000 population.

1.4 We estimate that in terms of biochemical oxygen demand, the total volume of palm oil waste discharged from mills in West Malaysia during 1970 would be equivalent to the domestic sewage from a population of about 6.5 million. We estimate that the population equivalent will have risen to about 9.0 million by 1974.

1.5 We emphasise the highly polluting effects of these wastes on receiving waters.

1.6 We consider that a standard of 30 mg/l (milligrams per litre) suspended solids and 20 mg/l biochemical oxygen demand could reasonably be imposed on the discharges from some of the palm oil mills in Malaysia.

1.7 We discuss in general terms possible treatment methods.

1.8 We make broad recommendations for interim methods of treating the wastes. We suggest treating the two principal wastes separately, using anaerobic digestion techniques for the clarification sludge and stabilisation pond treatment for the steriliser condensate. We estimate a capital cost for these methods of treatment of the wastes from a 10 ton f.f.b./hour mill to be within the range ℳ415,000 - 585,000.

1.9 We discuss possible methods of recovering useful by-products from the wastes, and we suggest certain approaches that are worthy of further investigation.

1.10 We recommend that particular attention should be paid to those mill operations which affect the volume or nature of the wastes.

1.11 We propose that detailed analytical studies should be carried out on the wastes at a number of carefully selected mills.

1.12 We recommend the initiation of certain specific experimental work better to assess the efficiencies of possible waste treatment processes and we estimate the costs of this work at ℳ50,000: This sum excludes staff and labour costs and the cost of the design and supervision of operation of the experimental plant.

1.13 We compare pollution attributable to palm oil mills with that from other major sources and tentatively conclude that palm oil wastes are probably the most significant single source of river pollution in Malaysia.

2. TERMS OF REFERENCE

In your letter of 28th August 1970 you agreed the terms of reference we set out in our letter to you of 5th August 1970; these are as follows:

2.1 To review existing data on the magnitude, the disposition and the predicted growth of palm oil producing centres.

2.2 To visit a small number of processing plants (say six) for the purpose of assessing production methods and basic production variations.

2.3 To review existing data on the average nature and biodegradability factors of the wastes or, if insufficient data exists, to propose and supervise analytical procedures for the carrying out of appropriate tests in mill laboratories.

2.4 To describe the various methods available for reducing the polluting factors in the wastes to standards set by national authorities, including recovery methods; and to make recommendations, with costs.

2.5 To describe broadly, by recourse to published or recorded facts, the scale of pollution problems arising from other sources, for comparison with those from selected oil processing mill wastes.

We emphasised in our letter that this Report would be no more than a preliminary review, dwelling on the problems broadly rather than in time-consuming detail and that we thought it should provide you with a basis and reference for future action, following which proposals for individual factories or groups of factories could be described in detail as and when the need arose.

3. SCOPE OF INVESTIGATIONS

Following preliminary meetings in West Malaysia during August attended by our Partner (then Partner-designate) Mr. J.R. Preston and Associate Mr. J.M. Sidwick, detailed investigations were carried out by Mr. Sidwick in West Malaysia between 9th and 16th September and again between 22nd and 30th October 1970. During these investigations we visited six palm oil mills and also attended many meetings to acquaint ourselves with the technical aspects of the general problem.

In addition to our investigations in West Malaysia, we initiated a literature survey into the nature, effects and treatment of palm oil wastes (Appendix A) and arranged for filtrability studies to be carried out on our behalf by the Water Pollution Research Laboratory at Stevenage, England (Appendix B). We also made contact with the Tropical Products Institute and the Rubber Research Institute in England and were advised by our Consultant, Professor P.C.G. Isaac of Newcastle University.

4. REVIEW OF EXISTING DATA ON THE MAGNITUDE AND PREDICTED GROWTH OF THE PALM OIL INDUSTRY

We have obtained some general data on the present and future production of palm oil and the total acreage of oil palms in West Malaysia and in Sabah. Some of these data are conflicting, but we think that the graphs attached to this Report (Figure No. 1) are probably realistic. These show a 1970 acreage under oil palm cultivation of about 700,000 in West Malaysia and about 750,000 including Sabah, producing about 450,000 tons and 500,000 tons of palm oil respectively. The graphs also show a progressive and rapid increase in West Malaysia and West Malaysia plus Sabah to about 950,000 acres producing 900,000 tons of palm oil and 1,000,000 acres producing 950,000 tons of palm oil by 1974. We understand that in the past palm oil production has tended to be concentrated in low lying coastal areas like the Klang Basin, but that much of the recent and future acreage is in inland areas where waste disposal is likely to create even greater problems.

The distribution of oil palm acreage according to States is shown in Figure 2.

5. THE PALM OIL EXTRACTION PROCESS AND MILL WASTE PRODUCTION

The crop of fresh fruit bunches (f.f.b.) varies widely depending on, for example, the maturity of the palms and the nature of the soil. We understand that average production from an established estate can vary from 4 tons f.f.b./acre/annum up to more than 10 tons f.f.b./acre/annum. However, assuming an average production of about 8 tons f.f.b./acre/annum and allowing acreage for immature palms and spare mill capacity for peak loads, we estimate that one mill of 10 ton f.f.b./hour capacity would be required for about each 5,000 - 6,000 acres of palms.

The fresh fruit bunches are cut and usually stacked before loading into railway wagons or road trucks for transportation to the mill. At the mill the bunches, sometimes after washing, are loaded into cages and run into a steriliser where they are held during a sterilisation period of about 60 minutes. Live steam under pressure is used to heat the fruit to about 140°C at a pressure of about 40 p.s.i.; lower pressures are sometimes employed at older mills. The length of the sterilisation period and the temperature and pressure are sometimes varied depending on the age and ripeness of the fruit. The condensed steam (steriliser condensate) is discharged to waste.

After sterilisation the bunches are stripped and the fruit is transferred to either a hydraulic or a screw press to extract the oil from the pericarp of the fruit.

The extracted crude oil is passed through a vibrating screen, often with the addition of hot water and then to a clarification tank from which clean oil is decanted after settlement of oily sludge to the bottom. The heavier fraction of the sludge is discharged directly to waste; the remainder is centrifuged, often after desanding and screening: the discharges consist of oil which is returned to the clarification tank and a sludge residue which is run to waste (clarification sludge).

The press cake and nuts are separated. The nuts are dried and cracked and the kernels separated from the shells before being bagged for sale. The press cake and some of the shells are burnt in the steam-raising boiler. The empty bunches are either incinerated to produce muriate of potash for estate use or resale, or they are occasionally spread between the oil palms as a mulch.

We attach a generalised flow diagram showing the mill processes (Figure No. 3).

In addition to the steriliser condensate and the clarification sludge, which are the principal wastes, discharges occur from a number of other points in an average mill; the most significant we list below:

1. Discharge from desander.

2. Discharge from clean oil centrifuge.

3. Discharge from Hydrocyclone or claybath separators.

4. Discharge from bottom of crude oil settling tank.

5. Floor drains.

6. Boiler blowdown.

7. Cooling water.

8. Discharge from steam traps.

9. Fresh fruit bunch wash water.

We have little information and no analytical data on these wastes. However, we understand that their volumes are low in comparison with those of the two main wastes and that they are not necessarily common to all mills. The first four discharges listed are likely to be of a similar nature to the principal wastes and probably could be treated with them without any need for additional treatment plant. Floor drainage is insignificant in terms of volume. Boiler blowdown, cooling water and discharge from steam traps are discharged at elevated temperatures, otherwise they are insignificant in terms of pollution.

In the absence of detailed data, we exclude these wastes from further consideration in this Report. We think, however, that their volume and nature should be assessed in any investigatory work that might be initiated in the future. Should they be shown to be more significant than we are at present led to believe, due allowance for their treatment can then be made in any proposed treatment plant.

5.1 Principal Palm Oil Mill Wastes

We discuss in detail below the two effluents which we believe to be of greatest significance.

Steriliser operation can vary, but the evidence we have suggests that the volume, nature and strength of steriliser condensate discharges probably vary comparatively little from mill to mill.

A number of different types of press are employed to separate the oil from the pericarp. The principal variation is the use of either hydraulic or screw presses. It is likely that the volume and solids content of the crude oil varies among different types of press; for example, we understand that screw presses often ultimately tend to produce more clarification sludge than hydraulic presses. However, we are unable to quantify these variations with any certainty, and therefore assume a similar centrifugfeed from all types of press. We are also unable to quantify any variations in the volumes of hot water that may be added and again assume constant operating conditions. We think these assumptions are realistic in the context of this Report.

There are two principal types of centrifuge generally in use: the Stork and the Westfalia. The limited information currently available suggests that the sludge produced from the latter contains the lower moisture content; experimental work at one mill has shown it possible to reduce the moisture content in Stork sludge to a level comparable to that from a Westfalia centrifuge, but at the risk of nozzle blockage.

In the course of our investigations we have accumulated considerable data relating to the volumes and nature of the two main wastes. Much of these data have been given to us by individual companies and are confidential; others we have abstracted from published work (Appendix A), principally that of Kirat Singh and Ng Siew Hoong (The Malaysian Agricultural Journal, Vol. 46, No. 3,January 1968). The work of Kirat Singh et al in particular, shows the wastes to be biodegradable and therefore amenable to standard sewage treatment techniques.

We set out (Table 1) data we believe to be fairly representative of average conditions in a generalised mill processing 10 ton f.f.b./hour and operating for 24 h/d. We have assumed figures for clarification sludge which we think could be attained at most mills and use these figures for calculation purposes; we do, however, also set out the ranges that seem currently to be attained in practice. We also relate the loads of the principal pollution parameters to 1 ton f.f.b. processed. In practice variations would be more likely to be in terms of volume and strength, the daily loads of pollutants probably remaining more constant.

In Table No. 1 we tabulate the primary parameters of Biochemical Oxygen Demand in five days at 20°C (B.O.D.), and suspended non-oily solids (filtered and then dried at 105°C)(S.S.). We also list possible oil, dissolved non-oily solids, ammoniacal nitrogen and organic nitrogen concentrations, chemical oxygen demand (C.O.D.) and pH value. In terms of the pollutional load on both receiving waters and waste treatment plants, the most important single parameter is B.O.D. B.O.D. and suspended solids are the two parameters that are normally controlled when limits are imposed on effluents discharged to rivers. Nitrogen concentration can be of importance when there is a risk of eutrophication of receiving waters, or when water is abstracted for drinking purposes below the point of effluent discharge. Both wastes are discharged at elevated temperatures which would be likely to aggravate any polluting effects in the vicinity of the point of discharge. We compare palm oil waste pollution with pollution attributable to other sources in Section 15.

5.2 Population Equivalent

Untreated domestic sewage in Kuala Lumpur and Singapore generally has a B.O.D. less than 200 mg/l and a suspended solids concentration of a similar order: the daily load discharged per head of population in these areas is about 0.09 lb B.O.D. and 0.10 lb. suspended solids. Were the biodegradability of the wastes similar to that of normal domestic sewage (Section 8.4), the population equivalent of the mixed effluent from a

Waste		Vol. (g.p.d.)	B.O.D			Suspended N.O.S.			Oil (%)	Amm.N. (mg/1)	Organic N (mg/1)	pH	C.O.D. (mg/1)	Dissolved N.O.S. (mg/1)
			(mg/1)	(lb/d)	(lb/ton f.f.b.)	(mg/1)	(lb/d)	(lb/ton f.f.b.)						
Steriliser Condensate		11,000	20,000	2,200	9	10,000	1,100	5	1.0	75	650	4.5	60,000	35,000
Clarification Sludge	Average	12,000	20,000	2,400	10	35,000	4,200	17	1.0	75	1,000	4.5	60,000	30,000
	Range	10,000 to 25,000	18,000 to 25,000	-	-	10,000 to 50,000	-	-	-	-	-	-	-	-
Mixed Effluent	Average	23,000	20,000	4,600	19	24,000	5,300	22	1.0	75	830	4.5	60,000	32,000
	Range	21,000 to 36,000	18,000 to 25,000	-	-	10,000 to 50,000	-	-	-	-	-	-	-	-

TABLE 1

10 ton f.f.b./hour mill would be about 51,000 in terms of B.O.D. and 55,000 in terms of suspended solids. Taken separately, and in terms of B.O.D. alone, the steriliser condensate would have a population equivalent of about 24,000 and the clarification sludge an equivalent of about 27,000. In terms of suspended solids, the clarification sludge has significantly the greater population equivalent; this is in the order of 42,000.

In terms of population equivalent and assuming one 10 ton f.f.b./hour mill for every 5,500 acres under cultivation, the 1970 palm oil production results in a total pollutional load equivalent in terms of B.O.D. to a population of about 6.5 million in West Malaysia and 7.0 million including Sabah: by 1974 the population equivalent will have increased to nearly 9 million in West Malaysia alone, which equates to the present total population. In terms of suspended solids these figures may be increased slightly. The annual total volume of mixed waste is likely to exceed 1,400 million gallons from the equivalent of more than 170 10 ton f.f.b./hour mills.

6. EFFECT OF THE WASTES ON RECEIVING WATERS

When discharged the wastes have a pleasant odour, but their high B.O.D. almost immediately produces anaerobic conditions in discharge drains and ditches. This situation is aggravated by the settlement of solids and their anaerobic decomposition. These effects were readily apparent in all the discharge ditches we saw in West Malaysia and the attendant odours were highly objectionable.

The ditches discharge to rivers, the quality of which is a matter of national and local interest. Rivers may be used for water-based amenities such as swimming, washing or fishing, they may pass kampongs and water may be abstracted from them for drinking purposes. This imposes an obligation on waste producers to treat or control discharges so as not to create either aesthetic or hygienic problems.

Definitive investigation of the effect of discharges on the various receiving rivers in Malaysia was outside the scope of this report, but the high B.O.D. of the palm oil wastes undoubtedly seriously reduces dissolved oxygen concentrations and this could readily lead to the development of anaerobic conditions; even partial oxygen depletion in receiving waters may upset the biological balance of those waters. It is also likely that settlement of suspended solids would produce objectionable banks of septic sludge in slow reaches of the rivers. Apart from aesthetic objections, it is possible that health is at hazard as a direct result of some of the palm oil waste discharges and in any case it is probable that there are few instances where the discharge of untreated waste could be shown to be acceptable.

7. STANDARDS OF EFFLUENT

The British Royal Commission on Sewage Treatment in its 8th Report issued in 1912 recommended standards for sewage works effluent discharged into British rivers. The severity of the standard was determined by the dilution available in the receiving waters at the point of discharge and by the methods of treatment available at that time. Their recommendations were as follows:

Dilution Available	Effluent Standard S.S. (mg/l)	B.O.D. (mg/l)
< 8	depending on local circumstances	
8 - 150	30	20
150 - 300	60	-
300 - 500	150	-
> 500	-	-

Experience since that time has shown these basic standards generally to be realistic and in Britain, as in many other countries, the common standard for the discharge of sewage and trade effluents to streams giving average dilution is still 30:20. In special circumstances where, for example, dilution is minimal or drinking water abstraction is practised downstream of the discharge, higher standards may be set, including a limit on the concentration of ammoniacal nitrogen. Increasingly, attention is being paid to the risk of eutrophication of receiving waters and it is likely that in the future it will prove increasingly necessary to remove nutrients (nitrogen and phosphates in particular) from effluents.

In U.S.A. where receiving waters often offer greater dilution than in Britain and Europe, partial treatment followed by chlorination was commonly practised, with standards of 50:50 or less. However, the increasing use of rivers for water abstraction and general aesthetic considerations have led to stricter standards and 30:20 or better is now more usual.

In tropical countries where river temperatures are higher, increasing the rate of biological activity and hence of dissolved oxygen uptake, and where dilution may be low in dry seasons, the need for high standards can often clearly be demonstrated.

We have attended a meeting with Mr. Sekarajasekaran, Public Health Engineer, Ministry of Health, when we were handed a copy of a draft of An Enactment to Amend The Waters Enactment, Cap. 146, which we attach to this Report (Appendix C). It is proposed that this amendment shall limit the discharges of all polluting matter into watercourses to those controlled by licence; the terms and conditions of licences to be laid down by the State Secretary of the State in which the river is located. We think it likely that this Enactment will become law and that licences ultimately will be required by all palm oil mills in Malaysia which discharge wastes into inland rivers. We do not know what terms and conditions are likely to be attached to these licences, but would hope that each case would be considered in the light of local conditions.

8. TREATMENT AND DISPOSAL OF THE WASTES

The wastes may be considered separately or as a single mixed waste. They may be discharged either directly, or after treatment, to the ground, to rivers or to the sea; or in part to the air after, for example, incineration. The degree and method of treatment would dictate the overall pollutional effects. Available methods of treatment and disposal should be assessed with a view to achieving acceptable levels of pollution by means economically and practically most suited to the nature of the wastes. We attempt to carry out an appropriate assessment in this Section.

8.1 Nature of the Wastes

The two principal wastes are of similar nature and produced in similar quantities. Both are highly polluting, with a heavy B.O.D. load, much of which is associated with finely-divided, colloidal or dissolved organic matter: both wastes are acidic and have a high oil content. The clarification sludge is characterised by having a larger concentration of suspended matter than the steriliser condensate. Both wastes are non-toxic and biodegradable.

8.2 Summary of Available Methods of Treatment and Disposal

We categorise below available methods of treatment:

1. Solids Separation

By gravity:	Settlement Flotation Centrifugation
By filtration:	Rapid sand filtration Slow sand filtration Sand drying beds Wedge wire drying beds Screening Upward-flow clarification Vacuum filtration Filter pressing Ultra-filtration
2. Chemical Treatment	Flocculation Oxidation
3. Heat Treatment	Low pressure High pressure (wet oxidation)
4. Incineration and Evaporation	
5. Biological Treatment	
Aerobic treatment	Biological filtration Activated sludge treatment
Anaerobic treatment	Anaerobic digestion Anaerobic stabilisation ponds
Facultative treatment	Facultative stabilisation ponds

6. Disposal Directly to the Environment

Disposal to a watercourse

Disposal to ground

Disposal to sea

Disposal to air

8.3 Unsuitable Methods of Treatment

8.3.1 Solids Separation

The finely-divided nature of the suspended solids militates against efficient solids separation and the large proportion of colloidal and dissolved solids present in both wastes minimises the effectiveness of solids separation as a means of reducing B.O.D.

The only methods which merit further consideration are vacuum filtration, using a pre-coated vacuum filter; and ultra-filtration. We discuss possible experimental approaches to these methods in Section 13, and we mention ultra-filtration again in Section 11 in the context of recovery.

8.3.2 Chemical Treatment, Heat Treatment, Incineration and Evaporation

For a variety of reasons we discard all these methods, with the exception of evaporation of the clarification sludge, which we discuss further in Section 11.

We do not dwell on the above methods or solids separation methods in any detail here but, for completeness and interest, we set down further comments in Appendix F.

8.4 Suitable Methods of Treatment - Biological Treatment

Biological treatment relies upon the ability of bacteria and other flora and fauna to utilise the organic constituents of a biodegradable waste as food, converting them into innocuous inorganic end-products. The process may be aerobic (relying upon the presence of oxygen), anaerobic (in the absence of oxygen) or facultative (intermediate between the others). Aerobic treatment proceeds at a more rapid rate and generally achieves much higher efficiencies and higher quality effluents. Anaerobic treatment is generally more suited to the partial treatment of very strong wastes.

We have said that work by Kirat Singh et al has shown the wastes to be biodegradable; this we would have expected.

A measure of the biological treatability of a sewage or industrial waste is the B.O.D:C.O.D. ratio. With domestic sewages, this ratio seldom exceeds 1:2. The ratios for both the steriliser condensate and the clarification sludge are of the order of 1:3 which implies that these wastes may be less readily biodegradable than domestic sewage; unfortunately, this can only be tested by carrying out experimental work.

In order to achieve the maximum rate of biodegradability sufficient nutrients must be present to permit efficient biological treatment; the most important of these are nitrogen and phosphorus. It is generally assumed that nitrogen and phosphorus do not limit the rate of bacterial metabolism providing that they are present in concentrations sufficiently great to give a N:B.O.D. ratio of at least 1:20 and a P:B.O.D. ratio of at least 1:100. On the basis of analytical work carried out on our behalf in West Malaysia we calculate that the following average ratios may be expected:

	Steriliser Condensate	Clarification Sludge	Mixed Effluent
N:B.O.D.	1:50	1:35	1:42
P:B.O.D.	1:120	1:100	1:110

Thus, both wastes are deficient in nitrogen; the steriliser condensate is slightly deficient in phosphorus. These deficiencies would be unlikely seriously to affect low-rate biological processes, but the addition of artificial nutrients, particularly nitrogen, might be necessary with high-rate biological treatment.

The acidity of the wastes may also inhibit biological treatment processes; these are generally most efficient when operated within the range pH 6.0 - 8.0. Many processes have an inherent buffering capacity, but it could be shown necessary to neutralise the wastes partially or completely prior to any biological treatment process, particularly one operated at a high rate.

8.4.1 Aerobic Treatment

The oxygen necessary to aerobic treatment processes may be supplied from the atmosphere by natural circulation through a medium (biological filtration), by natural dissolution through the surface of the waste (stabilisation ponds) or by mechanical aeration (activated sludge processes). Combinations of these techniques have been used (aerated ponds, forced-air ventilated biological filters, etc.) and plant efficiencies have been improved experimentally, but at high cost, by introducing oxygen gas in place of air. We discuss below the methods of aerobic treatment we think most suited to palm oil waste treatment.

8.4.2 Biological Filtration

The high solids content of the clarification sludge renders it unsuitable for biological filtration either alone or mixed with condensate; the economics of installing a plant capable of treating both the B.O.D. load and the large volume of secondary sludge would be unattractive.

It is possible that the steriliser condensate could be treated by biological filtration at an acceptable cost. The high strength of this waste makes it ideally suited to treatment by high-rate filtration, using synthetic medium; it would be necessary to use a multi-stage process with a high rate of recirculation, followed by a further stage of biological treatment (e.g. conventional biological filters or stabilisation ponds) to achieve a high effluent standard. Prior to treatment, neutralisation and nutrient addition could be necessary and treatment of secondary sludge would be required. We discuss this further in Section 13.

8.4.3 Activated Sludge Treatment

This process is generally not suited to the treatment of very strong wastes because of the high costs both of returning large volumes of treated effluent considerably to dilute the waste and of meeting the high oxygen demand mechanically. However, it is probable that both wastes would be amenable to treatment by the activated sludge process, but it would not be economically feasible so to treat the clarification sludge and the large volumes of surplus activated sludge would create additional disposal problems.

As in the case of biological filters, the condensate could be treated separately by the activated sludge system, and a sufficiently high degree of treatment probably could be achieved with a properly designed single-stage plant. There are many systems available and that which seems most suited to this application and which has the attendant merit of fairly low capital costs, is a Pasveer or oxidation ditch system. We also discuss this in greater detail in Section 13.

8.4.4 Anaerobic Treatment - Anaerobic Digestion

Kirat Singh et al found that the B.O.D. of a sample of mixed waste could be reduced from 20,500 mg/l to 6,000 mg/l after 25 days retention in a digester. They claimed that higher efficiency might be expected with a full-scale system but this is not in accord with our experience. However, further treatment would be necessary before discharge to a stream, probably by solids removal and aerobic treatment. The partial treatment of strong organic wastes by anaerobic digestion is practicable, but often not efficient. However, digestion as a means of sludge conditioning is common practice with collection and usage of gas produced from the process often being economically viable. The process itself tends to be more robust and efficient when the feed has a high solids content.

We think that the treatment of the clarification sludge by anaerobic digestion should be economically acceptable. During the digestion process, much of the oil and other organic material would be broken down with the production of a gas, primarily methane and carbon dioxide, with a calorific value of 700 - 750 B.T.U./ft.^{3}. The digested sludge would be comparatively innocuous, would probably be easier to dewater than the crude sludge and could either be disposed of directly to land, in liquid form or after dewatering, with little risk of trouble.

8.4.5 Anaerobic Stabilisation Ponds

The use of anaerobic stabilisation ponds is particularly applicable to the treatment of a strong biodegradable waste in the tropics to achieve a partial B.O.D. reduction. We think that this system would be efficient, but it has the disadvantage that smell problems could develop. Anaerobic ponds may be followed by facultative ponds and smell has satisfactorily been eliminated from anaerobic pond systems elsewhere in the tropics by recirculation of final facultative pond effluent to the anaerobic pond system inlet; the addition of sodium nitrate to the untreated waste has also successfully eliminated smell trouble, but is expensive.

8.4.6 Facultative Treatment - Facultative Stabilisation Ponds

Facultative ponds are operated at much lower loadings than anaerobic ponds. Solids in the untreated waste settle to the bottom of the ponds and digest anaerobically, but the overall pond loadings are sufficiently low to enable aerobic conditions to be maintained in the overlying water layer. This eliminates risk of smell. Facultative ponds operate most efficiently when algal growth is allowed to develop. Algae and bacteria actively break down organic material and remove nutrients and the algae may then be harvested for use as animal food. We discuss this aspect in Section 11. The facultative ponds may be aerated artificially to increase their efficiency.

The treatment of palm oil waste using facultative ponds alone would be impracticable because of the large pond areas necessary.

8.5 Disposal directly to the Environment

8.5.1 Disposal to a Watercourse

We have discussed in Section 6 the effect of disposal of the wastes directly to a watercourse and have said that there are likely to be few, if any, rivers in Malaysia where the wastes could be discharged satisfactorily without prior treatment.

8.5.2 Disposal to Ground

The mixed or the individual effluents separately could be treated on land by either broad irrigation or spray irrigation, the effluent discharging to a watercourse or by soakage. Broad irrigation of untreated wastes would require the setting aside of land specifically for waste treatment and possibly with cover crops. Spray irrigation of untreated wastes could be practised on land with growing palms, but could lead to scorching due to the high strength and low pH; the land could be adversely affected because of the high oil content and smell and fly nuisance would be likely. The disposal of treated clarification sludge, steriliser condensate or effluent from mixed waste treatment plant is more attractive: land requirements would be considerably less and there would be less likelihood of crop damage and nuisance.

8.5.3 Disposal to Sea

In certain coastal localities, disposal of the mixed wastes directly to sea could be the most economic means of disposal. However, each site would have to be considered on its merits and hygienic or aesthetic considerations might make it desirable to carry out appropriate investigations to determine the siting and length of the sea outfall. Economic comparisons would have to be drawn between long outfalls, partial treatment with short outfalls and full treatment with minimal outfall lengths.

8.5.4 Disposal to Air

Direct disposal of the wastes to atmosphere is, of course, not possible. We have discussed evaporation and incineration of the waste and both these methods of treatment would produce some atmospheric pollution, control of which might have to be considered. Aerial smell nuisance from other forms of treatment might also create problems.

9. PROPOSED INTERIM METHODS OF TREATMENT

In Section 8 we discussed a number of alternative methods of treatment in broad terms. In order to evaluate the efficiency and practicability of those methods most likely to be applicable to palm oil waste treatment we think that certain experimental work should be carried out; we discuss this in Section 13. An experimental programme is time consuming and in the meantime it might be necessary to install waste treatment facilities at some mills. We discuss below in general terms the methods of treatment we believe at this time to be the most economic and potentially reliable.

Process design data and estimated costs are set out in Appendices D and E. We also attach flow diagrams (Figure Nos. 4 and 5). We estimate that the full cost of treating the wastes from a 10 ton f.f.b./hour mill by the interim methods we propose would be within the range $M415,000 - 585,000 including supervision costs and engineering fees.

In the course of discussions and after an extensive literature search, we have not discovered any instances where the separate treatment of the two waste streams has been considered. However, the two wastes are basically different in nature: the clarification sludge, particularly that from Westfalia machines, is primarily a slurry; the steriliser condensate is primarily a liquid waste; both are highly polluting. Because of the different nature of the wastes, we think that there could be merit in keeping them separate and treating each differently, using those techniques most suited to their respective characteristics. Of the possible treatment methods discussed, we think the one most applicable to treatment of the clarification sludge is anaerobic digestion followed by liquid disposal to land; the steriliser condensate we think best treated in stabilisation ponds prior to discharge to the stream. We discuss these methods in greater detail below.

9.1 Treatment and Disposal of Clarification Sludge

Kirat Singh et al used a retention period of 25 days in their work. This compares with the 20 - 30 day retention period normally used for digestion of organic sludges in sewage and trade effluent treatment plants and should be sufficient to ensure adequate breakdown of oil and other organic matter and to produce an innocuous digested sludge for disposal.

The low pH of the waste could lead to the development of acid conditions in the digester. Analytical work carried out on our behalf in West Malaysia shows that it might be necessary to add at least 13 cwt. of lime to the daily output of clarification sludge from a 10 ton f.f.b./hour mill to achieve neutrality. However, Kirat Singh et al showed that the mixed wastes could be digested successfully without pH adjustment. We would expect a digester treating clarification sludge alone to be more robust and it is therefore possible that neutralisation of the feed may not be necessary; neutralisation could, however, be required, particularly at the commissioning stage.

In temperate climates it is necessary to heat the digesting sludge to a temperature normally within the range of 85 - 95°F. However, the ambient temperature in Malaysia is sufficiently high to enable the process to operate efficiently without artificial heating.

The digesters may be constructed either as open earth-banked lagoons or as concrete or steel tanks. Earth-banked lagoons are less costly to construct, but enclosed concrete or steel tanks allow greater control and reliability, create no smell nuisance, enable gas collection to be practised and are therefore to be preferred on technical and aesthetic grounds. The potential value of the digester gas should be considered in any economic evaluation; we estimate that at least 50,000 ft.^{3} of sludge gas should be produced daily with a total calorific value in excess of 35 x 10^6 B.T.U.

In order to give flexibility of operation it is desirable to duplicate the digesters and to construct at least one small secondary lagoon to act as a buffering tank between the digesters and final disposal.

We envisage that final disposal to land would be by a tractor-towed tanked. Digested sludge would be withdrawn from the secondary lagoon and sprayed between rows of oil palms. We do not think that this should affect the palms adversely, but advise the desirability of an experimental approach (Section 13)

In Appendix D we have considered both simple earth-banked digesters and concrete digesters with and without gas-collection facilities, since it might be considered that the extra cost of the more sophisticated design could be justified in the light of gas usage.

9.2 Treatment of Steriliser Condensate

This waste has a high B.O.D. (about 20,000 mg/l), but the volume discharged daily is comparatively low (about 11,000 g.p.d.). Anaerobic stabilisation ponds generally have been found to tolerate much higher loadings than facultative ponds and we consider, therefore, that this method of pond treatment is most suited to the treatment of the strong waste. Experience elsewhere in the tropics has shown that anaerobic ponds may be loaded considerably in excess of 6,000 lb. B.O.D./acre/d to achieve B.O.D. removal efficiencies up to 80 per cent or even greater. However, in view of the very high strength of the steriliser condensate and absence of experience with its treatment we think it would be imprudent to assume that efficiencies in excess of 50 per cent would be achieved. A series of five ponds would be needed to achieve a B.O.D. reduction to 625 mg/l. Anaerobic ponds show the highest B.O.D. removal when B.O.D. loading is highest: in Appendix E we consider comparatively conservative loadings which might be increased in the light of experience.

We think that reduction of B.O.D. below about 625 mg/l could best be achieved in facultative ponds. It is probable that one pond of 0.5 acre would be sufficient further to reduce the B.O.D. to about 125 mg/l. Finally, the achievement of an effluent of 30:20 standard (excluding algae) would require a second similar pond operating in series with the first.

The total pond area required for full treatment of steriliser condensate would be eight ponds with a total surface area of 2.25 acres (Figure No. 5).

Under tropical conditions both anaerobic and facultative ponds operate most efficiently when the pH of the pond contents exceeds 6.0. pH will increase during passage through a pond and the comparatively long retention periods we recommend will result in a significant buffering capacity within the system. However, it might prove necessary to increase the pH of the steriliser condensate prior to discharge to the first anaerobic pond by, for example, the addition of lime; the need for this can only be determined in practice.

Anaerobic ponds can be a source of smell nuisance: this can often be eliminated or reduced significantly by the recirculation of final facultative pond effluent. The use of recirculation is unlikely adversely to affect pond efficiency because of the comparatively long retention periods recommended and we advise that the facility to recirculate be provided.

It would be relatively simple and inexpensive to incorporate experimental facilities. We think that this is essential to determine maximum loadings and optimum operating techniques.

10. OPERATION OF PROPOSED TREATMENT PLANT

We consider that neither treatment facility would require either excessively time-consuming attention or full-time skilled supervision. Mechanical plant would be fairly simple and maintenance should be minimal. It could prove necessary to clean out both the anaerobic sludge digesters and the stabilisation ponds, particularly the anaerobic ponds, occasionally. Disposal of digested sludge to land would necessitate the permanent allocation of a tractor, tanker-trailer and driver to waste treatment and routine general maintenance of the digesters and ponds might require one or two unskilled men in addition. Regular attention to mechanical maintenance and overall technical supervision would also be required. Apart from the cost of labour, running costs would be limited to those of spares and electricity. Electricity consumption should not be high and would largely be limited to that required for the running of pumps.

11. RECOVERY

In preceding sections we have discussed general methods of waste treatment and have presented specific interim proposals. We are conscious that the methods we have discussed can show no financial benefits except, perhaps, the limited value of the liquid digested sludge as a fertiliser. The nature of the wastes suggests that their conversion into a product suitable for sale, for example by inclusion in animal foodstuffs, would be attractive and could show worthwhile economies. We are not qualified to discuss either the nutritional or microbiological aspects of recovery, but we think that we should comment in general terms on some possible lines of approach. We also discuss the possibility of reusing treated effluent, a practice that sometimes can be shown to be of economic advantage.

11.1 Evaporation of Clarification Sludge

We have mentioned the possibility of evaporation of clarification sludge (Section 8). In order to evaporate to dryness the total output of clarification sludge from a 10 ton mill, we calculate that there would be a daily heat demand of 175 x 10^6 B.T.U./d. We understand that existing mills produce very little spare heat and that the efficiencies of incinerators and boilers need not be high: increased efficiencies would be likely to lead to the availability of some excess heat. It might also be possible to use heat exchangers to recover some waste heat from the steriliser condensate, but additional heat would be required in the form of gas, oil or electricity. We have made certain broad assumptions, the validity of which would need to be confirmed experimentally, and tentatively conclude that the capital cost of a drier to reduce the moisture content of the clarification sludge produced by a 10 ton f.f.b./hour mill to about 5 per cent would be about $M1.75m. Fuel and maintenance costs could be of the order of $M0.25m. per annum.

We are aware of certain tentative approaches that have been made towards assessing the saleability of the dried material and that figures within the range of $M100 - $M160 per ton have been quoted, but understand that the reliability of possible commercial outlets is dubious. In our opinion, the nature of the material should make it suitable for inclusion in animal foods, with the possible exception of the inorganic (dirt) content but, before entering into any experimental programme, advice should be sought of a nutritional expert to establish the value of the end-product with more certainty. A reduction of the dirt content would doubtless improve saleability. Assuming that evaporated clarification sludge could be sold at $M150 per ton, annual revenue from this source would be about $M0.225m. from a 10 ton f.f.b./hour mill.

The use of digester gas as a heat source for the evaporation of the digested sludge is attractive. Unfortunately, we do not think it likely that this approach would be worth pursuing because the process of digestion would reduce the organic content of the sludge and hence its food value. There would also appear to be the risk that the digestion process could produce toxic by-products and the sludge might in consequence be less attractive to potential purchasers.

11.2 Ultra-filtration

It is possible that ultra-filtration techniques could be used to dewater the wastes, particularly the clarification sludge. The filtrate would require further treatment: the residue, after further drying, would be comparable to that from evaporation processes. We discuss this further in Section 13.

11.3 Culture of Micro-Organisms

We understand that proposals have been made that micro-organisms could be cultured in palm oil waste with separation of the micro-organisms for sale as a protein-enriched animal food supplement leaving an effluent with considerably reduced B.O.D. Possible micro-organisms suggested have been yeasts and filamentous fungi, and Professor W.R. Stanton of the University of Malaysia has made certain proposals relating to the possibility of the oil palm industry supporting an appropriate research project using filamentous fungi. We have been made aware of Professor Stanton's proposals and have briefly discussed them with him, but we are not qualified to discuss their validity. We think it likely, however, that any process involving micro-organisms culture could only be developed after time-consuming and perhaps costly research. We do not know if the possible complexity of the final process would be acceptable, or whether there would be reliable commercial outlets for any saleable end-product.

We understand that Professor Stanton has suggested that the B.O.D. of the mixed waste could be reduced by 90 per cent under the right conditions. Other workers primarily Lefrancois (Industri. Agr. et Alim. No. 9, 1953: No. 10, 1953: No. 3, 1955: No. 4, 1955: No. 3, 1961: No. 1, 1964: No. 6, 1964), suggested possible B.O.D. reduction of 70-90 per cent using yeasts. A 90 per cent B.O.D. removal efficiency is very high for plants producing high-protein foods, but could possibly be achieved if the plant were designed specifically for B.O.D. removal alone. If plant design and operation were directed primarily towards the recovery of micro-organisms, we think it likely that efficiency of B.O.D. removal would be within the range 50 - 70 per cent. Assuming that a 60 per cent reduction could be realised in practice, the mixed waste B.O.D. would be reduced to about 8,000 mg/l. Thus, even were the maximum likely degree of B.O.D. removal achieved in practice, the final effluent would still have a B.O.D. some forty times stronger than domestic sewage and further treatment would be required. However, treatment of the effluent in, for example, stabilisation ponds alone would be likely to be effective. Assuming 23,000 g.p.d. of effluent with a B.O.D. of 8,000 mg/l from a 10 ton f.f.b./hour mill, the area of stabilisation ponds necessary to achieve a 30:20 standard of effluent would be about 2 acres. The cost of an installation of this nature would be about $M120,000 compared to the cost for full treatment of separated wastes of $M415,000 to 585,000 (Section 9).

11.4 Algal Harvesting

In Section 9 we have proposed the use of stabilisation ponds for treatment of the steriliser condensate and in the preceding paragraph we have said that ponds could also be used for treating mixed effluent after its use as a substrate for micro-organism culture. In Section 13 we mention the possibility of treating the mixed waste in stabilisation ponds alone. Facultative ponds operate at maximum efficiency when algae are permitted actively to grow in them. The algal cells could be expected to contain up to 50 per cent protein and amino acids. Facultative ponds operated with an applied loading of 200 lb. B.O.D./acre/d should produce about 45 tons of dry cells/acre/annum. Thus, the pond system proposed in Section 9 for the treatment of steriliser condensate from a 10 ton f.f.b./hour mill could be expected to produce up to about 40 ton/annum of algal cells of which half would be proteins and amino acids. Some experimental work has been carried out into the possibility of harvesting algae by, for example, filtration or flotation: algal harvesting from the palm oil waste facultative ponds could produce a useful and saleable by-product for the enrichment of animal foods were harvesting shown to be possible. The removal of algae by harvesting would have the added advantage of reducing the suspended solids concentration of the pond effluent to a low level and in any case removal of algae might be essential where particularly stringent final effluent standards were imposed.

11.5 Re-Use of Treated Effluent

Investigations into the possible re-use of treated effluent are outside the scope of this Report and we have not examined the practical or economic aspects of effluent re-use. It is possible that the use of effluent, at least, for washing of fresh fruit bunches or for floor washing, could be economically attractive, but the extent of any additional treatment that might be necessary would require careful technical and economic assessment.

12. IMPROVEMENT TO MILL OPERATIONS

We are not competent to discuss general mill operation critically, but the individual processes affect the nature or volume of the wastes; we discuss in broad terms below those we think to be the most significant.

12.1 Bunch Collection

We understand that attempts are being made to improve the efficiency of bunch collection, one method being to collect the bunches onto nets for mechanical hoisting into trucks. An additional advantage of this type of loading method is a reduction in dirt content with an ultimate saving in mechanical plant wear and a reduction in the dirt content of the clarification sludge; this would be particularly beneficial were the sludge to be converted into a saleable by-product for animal food.

12.2 Press Operation

Mill efficiency requires that the presses are operated to produce maximum extraction of oil from the fruit. This is not necessarily compatible with minimum clarification sludge production, but any reduction in the volume of sludge ultimately produced from the clarification stage will show savings in waste treatment costs.

12.3 Sludge Centrifuge Operation

Clarification sludge centrifuges should be operated to produce maximum sludge solids concentration in order to minimise sludge treatment costs and improve treatment plant efficiency.

12.4 Oil Traps

At many mills the wastes are discharged via an oil trap from which oil may be decanted or skimmed off. At one mill we saw screw-down, funnel-shaped oil decanters which seemed extremely efficient in operation. We understand that decanted oil has a high free fatty acid concentration and therefore cannot be recycled through the mill, but that it can often be sold to local soap manufacturers. Whatever the system of waste treatment or disposal that may be practised or proposed, we think it essential that the oil content of all wastes should be kept to a minimum by efficient oil removal prior to discharge and we commend the funnel type of system.

13. PROPOSED EXPERIMENTAL WORK

13.1 Details of Experimental Work

13.1.1 Analytical Studies

We have based our proposals on limited reported data and on the little additional data that have been obtained for us. We think that it is essential that detailed and carefully planned analytical studies be made at a number of carefully selected mills to obtain a more reliable and fully comprehensive picture of the volumes, composition and nature of the wastes.

13.1.2 Anaerobic Digestion

We have recommended that the clarification sludge be treated by anaerobic digestion. We think it desirable that pilot-scale digestion experiments be carried out to assess digester efficiency, gas yield and optimum digester loadings.

13.1.3 Stabilisation Ponds

If a full-scale pond system is not likely to be installed in the near future, we recommend the immediate construction of a small stabilisation pond installation for the experimental treatment of steriliser condensate. This should be used to establish appropriate pond loadings and to assess various methods of pond operation. The possibility of treating the mixed waste in a second experimental pond system should also be investigated. In this case, at least two primary ponds operating in parallel would be used as sludge digesters.

13.1.4 Disposal to Land

We have said that digested sludge could be disposed of to land in liquid form. We recommend that the digested sludge from the pilot-scale digestion plant be disposed of to land in order to confirm that such disposal would be acceptable. The effects of disposal to land of effluents from the other experimental treatment plants should also be investigated.

13.1.5 High-rate Biological Filtration

We have also said that high-rate biological filtration of the steriliser condensate is feasible. We recommend that the efficiency of this method of treatment should be assessed by the initiation of appropriate pilot-scale studies.

13.1.6 Oxidation Ditch

Experimental work on a pilot-scale oxidation ditch treating steriliser condensate could usefully be initiated to compare this form of treatment with high-rate filtration; both partial and full treatment could be investigated. Effluent from the partial treatment oxidation ditch and from the high-rate filters could be treated in an experimental stabilisation pond system.

13.1.7 Pre-coated Vacuum Filter

The possibility of dewatering the clarification sludge using a pre-coated vacuum filter has been discussed. We think it unlikely that this system would be economically viable even if the poor filtrability of the sludge permitted its application. However, were it to prove possible to dewater the sludge by this means without the addition of a chemical coagulant, the reduced moisture content would render evaporation more attractive economically. Additionally, the use of a suitable inert pre-coat material might not militate against the inclusion of the dried sludge in animal foodstuffs. We think, therefore, that the possibility of using a pre-coat vacuum filter should be examined experimentally.

13.1.8 Ultra Filtration

We have discussed the possibility of applying ultra-filtration techniques either to the mixed wastes or to the clarification sludge. We think this to be worthy of further study and recommend that investigations be carried out using appropriate bench-scale filter apparatus.

13.2 Costs of Experimental Work

We envisage that the experimental work should be carried out at mills or Research Stations in Malaysia and would expect the work involved to be carried out by existing staff. We would not therefore expect any additional staff or labour costs to be incurred.

We have not considered the design of the experimental plants in detail. However, we think that it should be possible to construct suitable plant for anaerobic digestion and stabilisation pond experimental work using plant and materials readily available at most mills. The capital costs of these plants should therefore be insignificant.

In order to assess the efficiency of high-rate biological filtration it would be necessary to construct a minimum of four filtration towers operating in series, each packed with synthetic medium; pumping facilities would also be necessary. We estimate that the approximate cost of a suitable simple installation would be $M40,000.

An oxidation ditch could be constructed using local plant and materials at little cost. However, a motor-driven aeration rotor would be necessary; we estimate that the cost of this, together with a suitable electric motor, would be about $M8,000.

The cost of pre-coated vacuum filtration experiments would depend on the availability on loan of a suitable pilot-scale filter in Malaysia. If one were available costs would be minimal, otherwise a suitable machine would have to be purchased.

The cost of special equipment for ultra-filtration experimental work would be low. We think that the bench-scale filtration apparatus would be unlikely to cost more than about $M2,000.

Provided a pre-coated vacuum filter is available on loan in Malaysia and excluding staff and labour costs and the cost of using locally available materials and equipment, it is likely that the total financial commitment in experimental plant need not exceed about $M50,000. This sum also excludes the cost of the design and supervision of operation of the experimental plant.

13.3 Duration of Experimental Work

The design of the experimental plant and the experimental programmes would require careful planning in order to ensure that maximum benefit resulted from the work. We do not know how either this work or the constructional work would be carried out and we cannot therefore estimate time requirements.

We would envisage that the experimental work itself could last for perhaps two years with an overall review every six months. It is likely, however, that much of the work would be completed within the first twelve months.

14. FUTURE TRENDS

We understand that research is currently being carried out into the possibilities of substituting either synthetic detergent or solvent extraction of oil for current practices. We do not know if either of these techniques is likely to be adopted in the future, but either would present new waste problems that should be considered prior to embarking upon any major or full-scale investigation into these new techniques.

In more general terms, we recommend that any changes to mill operations should be considered also in the light of their effects on the mill wastes.

15. POLLUTION FROM OTHER MAJOR SOURCES

There are two major industries in Malaysia discharging large volumes of highly polluting organic wastes to watercourses: the rubber industry and the pineapple canning industry. The rubber industry is represented throughout Malaysia whereas the pineapple canning industry is centred in South Johore, West Malaysia, with a single canning factory also at Klang in Selangor. We discuss these wastes in more detail below and attach production and acreage graphs (Figure Nos. 6 and 7).

It is likely that tin tailings from tin mines have a polluting effect on watercourses, but this is probably due mainly to high concentrations of comparatively inert suspended matter. Both organic and inorganic pollution is also likely from general industry which is primarily centred in the Kuala Lumpur and Petaling Jaya area of Selangor. It is not within our terms of reference to discuss these sources of pollution in detail.

Pollution of watercourses from domestic sources is also likely to be of significance. We discuss pollution by domestic sewage in more detail below.

We wish to emphasise that the comparisons that we draw among the various major sources of pollution are based on broad assumptions only and that detailed investigations could significantly affect our tentative conclusions.

Domestic Sewage

We know of only one major sewage treatment works in Malaysia. This works treats sewage from perhaps half of the Municipality of Kuala Lumpur by primary sedimentation only: the works effluent discharges to the Klang River. The rest of Kuala Lumpur and all other urban areas rely mainly on septic tank treatment and nightsoil collection: in neither case should there be major pollution of watercourses. We understand that pertinent reports have been produced by the World Health Organisation, but that these are not available to the public: we are also aware of prospective sewage treatment plans for a number of the principal towns in Malaysia. To our knowledge, no river pollution surveys have been carried out, but we think that there is an awareness of the effects of domestic sewage discharges and that steps are likely to be taken to reduce these effects. We have said in Section 5.2 that the population equivalent of the total palm oil processing waste discharge in West Malaysia in 1974 will equate to the present population of 9 million.

Much of the domestic sewage does not drain directly to watercourses and, apart from major towns, the sources of pollution are scattered; it is probable, therefore that the overall polluting effects of domestic sewage discharges are generally much less significant than those created by palm oil processing wastes.

Pineapple Canning

We have obtained canning pineapple production figures for West Malaysia for the years 1961 to 1968. We have plotted these figures (Figure No. 7) and extrapolate to give an estimated production of 300,000 tons during 1970.

We have been unable to discover any data relating to pineapple cannery waste production. On the basis of our general experience with cannery wastes, we think it possible that the canning of 1 ton of pineapple will result in the discharge of about 3,500 gallons of waste with a B.O.D. of about 1,000 mg/l (this is a population equivalent of about 400). This waste is likely to be acidic and deficient in nutrients: suspended solids concentration should be comparatively low.

We understand that the peak canning seasons are July/August and again in December but that hormone techniques are being applied to reduce seasonal fluctuations. Since all but one of the four canning factories remain in production throughout the year and seasonal fluctuations are progressively lessening we think it reasonable to assume peak discharges of twice average and to discuss this assumption in the context of this Report. On this basis, the total population equivalent of pineapple cannery waste is currently of the order of 300,000. This is small compared to palm oil processing wastes, but the total discharge is at present limited to four factories only, and locally to these pollution is likely to be serious. However, waste from a single large canning factory is approximately equivalent in terms of pollution only to that from a single 10 ton f.f.b./hour palm oil processing mill.

Rubber Processing

We have examined the limited information available on rubber processing wastes and have discussed the problem with representatives of some interested companies and with the Rubber Research Institute.

We understand that rubber estates are generally concentrated near the West Coast of West Malaysia and close to railway lines. However, rubber is produced throughout West Malaysia and elsewhere in Malaysia and in Table 2 we set out production on estates and smallholdings in West Malaysia for July 1970 (Monthly Statistical Bulletin of the Rubber Producers' Council of Malaya, Vol. 19, No. 9).

Production in tons

State	Estates	Smallholdings	Total
Johore	13,887	15,665	29,552
Kedah & Perlis	6,158	6,986	13,144
Kelantan	1,555	2,908	4,463
Malacca	4,594	3,531	8,125
Negri Sembilan	9,742	4,171	13,913
Pahang	3,134	5,099	8,233
Penang & P.W.	1,058	1,826	2,884
Perak	7,777	8,701	16,478
Selangor	9,685	4,464	14,149
Trengganu	360	1,519	1,879
Total, July 1970	57,950	54,870	112,820

TABLE 2

We understand that estates seldom exceed about 20,000 acres and that an average estate size is about 6,000 - 7,000 acres. Rubber production is fairly equally divided between estates and smallholdings (Table No. 2 and Figure No. 6). Smallholders tend either to process their own rubber or to use small village factories: in either case sheet or crumb rubber is produced. Estates rubber is processed either at estate factories or at larger, centralised factories: the latter often produce latex concentrate. About 20 per cent of all latex produced is processed as scrap rubber, the remaining 80 per cent may be processed into latex concentrate, sheet rubber, crumb rubber, crêpe rubber or other special grades. It is not within our terms of reference to examine rubber processing or process wastes in depth. However, we understand that the waste from latex concentrate factories is more concentrated than the wastes produced from other processes, but it is likely that the overall pollutional load discharged for each unit weight of rubber produced varies comparatively little among the various processes. The nature and strength of the wastes vary widely, but most of the primary wastes have a high B.O.D. and nitrogen concentration of up to at least 20,000 mg/l and 3,500 mg/l respectively: wash waters are less strong.

We have tentatively calculated the population equivalents for rubber wastes and think it possible that the total population equivalent of all the waste from the rubber processed in West Malaysia during 1970 will be of the order of 3 million. This compares to a population equivalent of 6.5 million for the palm oil processing wastes for 1970 (Section 5.2). However, much of the rubber processing waste will be discharged in very small volumes and it is likely that the overall polluting effects will be less significant than the population equivalent implies. Nevertheless, one figure supplied to us shows that a particular latex concentrate factory may discharge waste equivalent in terms of B.O.D. to a 20 ton f.f.b./hour palm oil processing mill.

16. ACKNOWLEDGEMENTS

We wish to acknowledge with gratitude the assistance that has been given freely by everyone with whom we have had contact, both in West Malaysia and in England. We would particularly like to express our thanks to the Director of Messrs. Harrison & Crossfield's Oil Palm Research Station, Banting and of the Chemara Research Station, Seremban, for the analytical work they have carried out on our behalf and to Mr. J.H. Maycock of Pamol (Malaya) Sdn.Bhd. for arranging for a sample to be supplied to us in London for special investigation.

Yours faithfully.

APPENDIX A

Treatment of Palm Oil Process Waste Waters

Literature Search on Behalf of

Messrs. J. D. and D. M. Watson

by

Water Pollution Research Laboratory

Stevenage, England

At the request of J.D. & D.M. Watson, Chartered Civil Engineers, the Laboratory has carried out a literature search on the treatment of palm oil process waste waters. Because of the apparent sparsity of information on this subject - only one paper was found which referred specifically to palm oil wastes, the search was widened to include treatment of wastes from the processing of olive oil and vegetable oils. The search has extended from current literature back to papers published in 1935.

Coagulation and Settlement

Chemical coagulation and settlement is a procedure normally employed for the treatment of fatty oil wastes (1-3). Tanaka and Yamate (1), in experimental work on the chemical treatment of waste waters containing fatty oil, obtained good results by chemical coagulation with aluminium sulphate, ferric sulphate, and sulphuric acid, 98 - 99 per cent of the fatty oils being removed, and a reduction in BOD of 58 - 87 per cent being achieved. However, the treated waste waters still had a BOD of between 300 and 500 mg/l. The treatment of the combined wastes from a factory producing soap and vanaspati, a vegetable oil product similar to margarine, was studied by Basu (2). He found a promising method of treatment to be coagulation followed by sedimentation. Alum, ferrous sulphate and bentonite, ferric sulphate, lime, and ferric chloride were tried as coagulants, and of these ferric chloride and alum appeared to be the most satisfactory, the former reducing the COD and suspended-solids content of the combined waste (initial values: COD 4990-10 950 mg/l; SS, 1480-7440 mg/l) by 97 and 99 per cent respectively while the latter gave corresponding reductions of 96.2 and 97.1 per cent. The dose of coagulant used to achieve these reductions was 300 mg/l in each case. Lower doses were also tried but no detailed investigation to find the optimum dose was attempted.

Cunningham (3) found aluminium sulphate and ferric chloride to be reasonably satisfactory as coagulants for waste waters from an edible-oil refinery and margarine factory, but with both coagulants it was necessary to add lime to achieve a satisfactory rate of settlement. Further experiments showed that addition of lime and caustic soda, with adjustment of pH value to 10.5 gave satisfactory flocculation, and this procedure was adopted. The average BOD of the effluent from the clarification plant was 400 - 500 mg/l and its suspended-solids content was of the order of 100 mg/l. Since Cunningham gave no figures for the composition of the raw waste waters, it is not possible to estimate the percentage reductions achieved.

In the only reference dealing specifically with palm oil, Singh and Hoong (4) suggest that coagulation may not be a suitable method for the treatment of these wastes. They do not give much detail on this, but merely say "Attempts were made to treat the effluent by coagulation and flocculation by using varying doses of lime, alum and ferric chloride. No floc could be obtained with even up to 4000 ppm of alum or ferric chloride".

Anaerobic Digestion

Oily waste waters have been satisfactorily treated by anaerobic digestion. Capodacqua (5) found that waste waters from olive oil factories which have a high content of organic matter can be treated by neutralization with milk of lime and digestion of the sludge with sewage sludge provided the proportion of the former does not exceed 25 per cent.

Singh and Hoong (4), having failed to coagulate palm oil wastes, found that they could be treated by anaerobic digestion, in laboratory scale digesters, at room temperature (22-33°C in their case) provided the detention period was between 20 and 25 days. The results they obtained are given in Table 1.

Table 1. Average BOD and permanganate value reduction in the palm oil mill effluent during a 25 day detention period in the digester (4)

	Average BOD	Average permanganate value
Untreated palm oil mill effluent	20500 ppm	4500 ppm
Treated effluent from digester	6000 ppm	795 ppm
Percentage reduction	70.7	82.5

They thought that with regular dosing and continuous stirring a greater reduction in BOD could be obtained, and saw no reason why the process should not work on a large scale. However, assuming a 90 per cent removal of BOD under ideal conditions they concluded that the BOD of the effluent would still be about 10 times that of raw sewage, and that although further purification by dilution followed by aerobic treatment in a percolating filter or oxidation pond would be possible the overall cost of treatment would be unacceptably high. It is possible that the climate of opinion may have changed since then. Singh and Hoong subsequently considered the possibility of disposal of the waste in water, on land, and as an animal feed. They concluded that the most economic method of disposing of the effluent was by discharge into the sea, and that it was therefore desirable in future to site palm oil mills near the coast.

Basu(2) appears to have obtained rather better results in the anaerobic digestion of vanaspati waste. His laboratory-scale digesters were run at room temperature (30-35°C) with detention times of 20 days in the primary digesters and 10 days in the secondary digesters. Gas production was about 20 volumes for each volume of waste digested. He found that high grease content and low temperature (about 25°C and below) caused failure of digestion. His results are shown in Table 2.

Table 2. Results of anaerobic digestion of vanaspati waste(2)

Item of analyses*	Influent	Primary effluent	Secondary effluent	Overall
Concentration(mg/l)				
Suspended solids	4350.0	435.0	130.5	-
COD	8210.0	820.0	418.5	-
Removal (%)				
Suspended solids	-	90.0	70.1	97.0
COD	-	90.1	49.0	94.9

* Average of four random results

Digestion in lagoons has been used for the treatment of waste waters from the cleaning of edible oil bunkers on tankers (6). The bunkers are cleaned using alkaline agents and the waste water has a pH value of 9-10 and a content of fats and fatty acids (ether extractable substances) of about 5 g/l or more. In Hamburg, seepage basins were used for disposal of these waters; the subsoil became clogged, seepage ceased and the capacity of the basins became exhausted. Addition of actively digesting sewage sludge increased scum formation, gave a sharper division between scum and liquid, and reduced the ether extractable material in the liquid by about 50 per cent. Experiments showed that on treatment with calcium chloride a scum formed which settled in 1 - 2 days; the supernatant liquid was slightly turbid and had a pH value of about 7.5. Removal of ether-extractable material, calculated on the liquid previously treated with sludge, was 85.4 per cent; calculated on the untreated waste the average was 94 per cent.

Biological Filtration

Paleni(7) has employed the Ingram controlled biological filtration process in packed towers (8) to treat the waste waters from a vegetable oil refinery and chemical plant, which had a BOD of 5000-19000 mg/l and an average pH value of 1.5. The effluent had a BOD of 50 mg/l and a pH value of 7.0.

Other Patented Methods

Bradford (9) has claimed the development of a process for the treatment of condensate from the steam deodorizers in a vegetable oil refinery. When sea water, which contains large quantities of calcium and magnesium ions, is used to condense the vapours, the calcium and magnesium react with the free fatty acids to form insoluble soaps which tend neither to settle nor float in the condensate. In the method claimed for treating this type of condensate, it is mixed intimately with a second waste water which is aerated and carries fine solid particles or a precipitate, and then passed to a quiescent zone where the floc and precipitate of both wastes float to the surface of the combined liquors. In a modification of the process, the second waste liquor, containing precipitate, comprises another waste liquor produced in the refinery (known as floor waste), which contains large quantities of soluble soaps, fats, and some protein materials; the process then provides efficient treatment for both wastes.

Foley (10) claims that the BOD and fatty acid content of wash waters from alkali refining of vegetable oils can be reduced by the addition of 25 - 30 grains of lignin per gal. The waste water is maintained at a temperature of 140° - 160° F and acidified with sulphuric or hydrochloric acid to a pH value of 3.0 - 2.0. On standing, a supernatant fatty layer separates out.

In a method for treating waste waters containing oil from canning fish or from manufacture of vegetable oils (11), the wastes are thoroughly mixed so that the oil is broken up and dispersed throughout the liquid in the form of particles less than 10 microns in size. The waste is discharged into a large body of water in which currents are sufficient to prevent agglomeration of the particles.

References

1. Tanaka, Y., and Yamate, N. Studies on industrial wastes. I. Studies on the treatment of fatty oils waste. Bull.nat. Inst. Hyg. Sci., Japan, 1960, No. 78, 119 - 124.

2. Basu, A.K. Treatment of effluents from the manufacture of soap and hydrogenated vegetable oil. J.Wat.Pollut. Control Fed., 1967, 39, 1653 - 1658.

3. Cunningham, R.J. Effluent problems in an edible oil refinery and margarine factory. Chemy Ind., 1965, 1481 - 1484.

4. Singh, K., and Hoong, N.S. Treatment and disposal of palm oil mill effluent. Malay. agric. J., 1968, 46, 316 - 323.

5. Capodacqua, M. Admission of waste waters from oil works to sewers. Ingegn. sanit., 1953, No. 3, 9 - 11.

6. Jaegers, K., and Haschke, J. A new process for treatment of waste waters from the cleaning of edible oil bunkers on tankers. Staedtehygiene, 1956, 7, 280 - 282.

7. Paleni, A. Controlled filtration of waste water containing fatty matter. Fette Seifen Anstr. Mittel, 1966, 68, 272 - 273; Chem. Abstr., 1966, 65, 6907.

8. Ingram, W.T., and Edwards, G.P. The behaviour of filter biota under controlled conditions. Int. J. Air Wat. Pollut., 1961 (1963), 5, 215 - 217.

9. Bradford, P., (to Swift & Company). Treatment of refinery wastes. U.S. Patent 2,925,383.

10. Foley, M.B., (to A.E. Staley Manufacturing Co.), Treatment of wash waters from alkali vegetable-oil refining. U.S. Patent 2,784,161; Chem. Abstr., 1957, 51, 7744.

11. Stenzel, R.W. (to Petrolite Corp.). Treating oily waste waters such as those from fish-canning or vegetable-oil plants. U.S. Patent 2,303,588; Chem.Abstr., 1943, 37, 2500.

September 1970
(WPRS 42/35/17)(RW 396)
WPR Report No. 330R

APPENDIX B

Effect of Flocculants on Filtrability of Palm Oil Sludge

by

Water Pollution Research Laboratory

Introduction

Palm-oil clarification processes produce a sludge which presents difficulties in disposal. A sample of this sludge from Pamol Estate, Kluang, Malaysia, was treated with sodium pentachlorphenate to give biological stability and despatched on 5th October, 1970. The sample was tested at the Laboratory for the effect of flocculants on the dewatering characteristics on 22th to 26th October, 1970.

Published information (see WPR Report 330R) suggested that palm oil wastes were very difficult to flocculate, and tests carried out at the Laboratory in 1966 had shown that aluminium chlorohydrate was ineffective as a flocculant with this type of sludge.

In the absence of any fundamental data on the physico-chemical nature of the sludge particles, the approach used in this brief investigation was to test the effect of a range of different types of flocculant, at different pH values, each at only one or two dosages, rather than studying one or two flocculants under a wider range of conditions.

Sludge Properties

The sludge as received had a pH value of 4.1 and a total solids content of 8.9 per cent. The filtrate obtained by filtering through a No. 17 Whatman paper, and then further filtering the liquor through a GFC paper, contained 4.3 per cent solids (i.e. almost half of the total solids were in the liquid phase). The total solids in the sludge had an organic and volatile content of 88 per cent, and the total solids in the filtrate an organic and volatile content of 84 per cent.

The filtrate obtained from a sample of sludge diluted 1:1 with water had the following properties:

COD	11750 mg/l
Organic carbon	4150 mg/l
Nitrogen (ammoniacal plus organic)	100 mg/l (approx.)
Total solids	22300 mg/l

In spite of the presence of sodium pentachlorphenate the BOD test gave a value of 6100 mg/l.

Because the sludge was extremely thick and would not flow easily it was diluted 1:1 with water for all the flocculation tests.

Effect of Flocculants.

Table 1 shows the capillary suction times (CST) obtained with the untreated sludge and when treated with aluminium chlorohydrate, Primafloc C7 (a low viscosity cationic polyelectrolyte), Magnafloc R292 (a high viscosity cationic polyelectrolyte), and Magnafloc R155 (an anionic polyelectrolyte), all in the absence or presence of lime. Ferrous sulphate with lime was also tested.

CST is essentially the time required to withdraw a given amount of filtrate from a sample. An improvement in filtrability is therefore associated with a reduction in CST.

The abnormal properties of the filtrate are reflected in the fact that the CST of filtrate alone was 20 s rather than, say, 8 s obtainable with water or most sewage-sludge filtrates.

The addition of lime alone to the sludge raised the CST, as did aluminium chlorohydrate alone and combinations of the two.

Primafloc C7 alone produced some lowering in CST though not when used in combination with lime.

Table 1. Effect of flocculants and of time of stirring, at 1000 rev/min, after initial mixing on CST of palm-oil sludge, using 10-mm reservoir. (Suspended solids content 2.1 per cent. Sample volume 25 ml. 5 ml of diluted flocculant added in each test. Lime added as 10 per cent suspension)

Flocculant	Dose (per cent by weight of suspended solids)		CST (s) after stirring for time shown			pH value
	Lime	Flocculant	Nil	10 s	40 s	
Nil. Filtrate only	–	–	20			
Nil. Sludge only	–	–	93			
Aluminium chlorohydrate (dose expressed as Al_2O_3)	–	5.1	190	–	200	3.9
	11.5	–	2200			
	11.5	5.1	more than 2000			
	23	–	1600			
	23	5.1	more than 2000			
Primafloc C7 (cationic)	–	1.1	47	54	62	4.2
	11.5	1.1	117	184	326	
Magnafloc R155 (anionic)	–	1.1	99	89	73	
	11.5	1.1	640	290	280	9.6
	23	1.1	156	117	137	11.0
Magnafloc R292 (cationic)	–	0.13	57	56	55	
	–	0.44	59	56	56	4.1
	–	1.1	72	71	70	
	11.5	0.44	60	46	38	9.4
	11.5	1.1	62	53	49	9.6
Ferrous sulphate	29	11.5	more than 2000			11.5

Magnafloc R155 was ineffective, and when used with lime gave an increase in CST.

Magnafloc R292 gave a slight lowering in CST and, somewhat surprisingly, the performance was very little influenced by the presence of lime.

Table 2 gives the results of measurements of specific resistance to filtration. The sludges treated with flocculants gave higher values than the untreated sludge. This confirmed that it was not merely the combination of the CST method of measuring filtrability with this rather abnormal sludge which was giving results indicating a lack of effectiveness of flocculants.

Table 2. Specific resistance of palm-oil sludges

Sample	Specific resistance (10^{13} m/kg at 49 kN/m^2)	pH value
Untreated undiluted sludge	48	-
Untreated sludge diluted 1:1 with water	6.6	4.7
Diluted sludge with 11.5 per cent lime and 1.1 per cent R292	10.2	10.9
Diluted sludge with 11.5 per cent lime, 5.1 per cent Al_2O_3, and 0.6 per cent R155	13.0	8.8

Other Methods of Treatment

In view of the failure of flocculants to improve the dewatering characteristics appreciably other factors were examined briefly.

A sample of undiluted sludge was frozen and then thawed. The CST using the 18-mm reservoir was reduced by the treatment from 110 s to 90 s.

A 10-ml sample of the diluted sludge was centrifuged at 1000 g for 10 minutes. The volume of sediment after the treatment was 4 ml, i.e. only 20 per cent less than the 5 ml occupied by the sludge before dilution.

The calorific value of an oven-dried sample of sludge was about 19 000 kJ/kg total solids, i.e. at the lower limit of the range for sewage sludges. Assuming an incinerator operating with 50 per cent air and an exit gas temperature of 430°C the solids content for autothermic combustion would be say 25 per cent. Considerable auxiliary fuel would therefore be needed for incineration of the sludge containing 9 per cent solids.

Conclusions

This brief investigation has shown that palm-oil sludges have characteristics quite different from those of other organic sludges encountered at the Laboratory. In particular the filtration characteristics do not appear to be improved by a variety of flocculating agents, some of which would be expected to be very effective with normal organic sludges. It is considered that progress in improving the situation is likely to result only from a fairly extensive programme of work based on a fundamental examination rather than from continued empiricism. The results of the present exercise hold out no special hope that such a programme would quickly reach a successful conclusion.

November 1970
(WPRS 42/35/17)(RW 399)
WPR Report No. 337R

APPENDIX C

An Enactment to Amend the Waters Enactment,
Cap. 146

IT IS HEREBY ENACTED by the Legislature of the State of as follows:

Short title

1. This Enactment may be cited as the Waters (Amendment) Enactment, 1970.

New section to be included in the Waters Enactment Cap. 146

2. The Waters Enactment Cap. 146 (hereinafter referred to as "the principal Enactment") is hereby amended by deleting section 2 thereof and substituting therefor the following new subsection (2)

"(2) In this Enactment "river" includes a tributary of a river and any other stream, canal or natural water course; provided however for purpose of section 7A the word "river" also includes:

(a) any inland waters whether or not such inland waters fall within the above definition;

(b) any subterranean water resources, and

(c) any water in an estuary or sea adjacent to the coast of the State."

3. The principal Enactment is hereby amended by inserting between sections 7 and 8 thereof the following new section.

"Prohibition of pollution of rivers.

"7A (i) Save as may be expressly authorised under the provisions of any written law or the terms of any express grant made by or on behalf of the Ruler of the State no person shall except under and in accordance with the terms and conditions of a licence issued under this section cause to enter or discharge into any river or State waters -

(a) any poisonous, noxious or polluting matter that will render or is likely to render or contribute to rendering such river or part thereof harmful or detrimental or injurious to public health, safety or welfare, or to animal or vegetable life or health or other beneficial uses of state waters; or

(b) any matter which by virtue of its temperature, chemical or biological content or its effect in discolouring the waters makes or contributes to making such waters or river or part thereof a potential danger to public health, safety or welfare or to animal or vegetable life or health, or affects other beneficial uses of the waters of the state.

(ii) Whenever any such entry or discharge shall have been made, the owner or occupier of the property from which such entry or discharge originates shall, in the absence of proof to the contrary, be presumed to have made it.

(iii) Licence to enter or discharge into a river any of the matter described in sub-section (i) of this section may be granted by the State Secretary of the State in which the river or part thereof is located.

(iv) Every licence granted under this section shall set out the purpose for which the same is granted and shall be for such period and such conditions and restrictions as may be laid down in the licence.

(v) The State Secretary shall have power at any time without cause assigned to -

(a) refuse to grant a licence; or
(b) revoke any licence issued under this section; or
(c) alter to vary the period, terms and conditions of any such licence.

(vi)

(a) Any person aggrieved by the decision of the State Secretary may within twenty-one days of the receipt of the notification of such decision appeal to an appeal board of the State in which the application for a licence under this section was originally made.

(b) An appeal board referred to in the preceding sub-paragraph (a) shall comprise the following members from the State or their representatives.

1. Mentri Besar.
2. State Legal Adviser.
3. State Commissioner of Lands and Mines.
4. Chief Medical & Health Officer.
5. State Drainage & Irrigation Engineer.
6. One representative from the private sector to be appointed by the Ruler in Council.

(c) On receipt of an appeal, the appeal board shall convene a meeting and adopt such procedure and make such decision as it deems fit.

(vii) No compensation shall be payable to any licensee whose licence is revoked, altered or varied in accordance with sub-section (v).

(viii) The Ruler in Council may for the purpose of determining the conditions and restrictions to be prescribed on licences issued under sub-section (iii) appoint a committee consisting of such persons as may be prescribed.

(ix) The Ruler in Council in appointing such Committee shall take into consideration the need to protect public health, safety and welfare and animal and vegetable health and life as well as the need to promote industrial growth and to protect other beneficial uses of state waters.

Amendment to section 9(i).

4. Section 9(i) of the Principal Enactment is hereby amended by inserting the following proviso thereto:

"Provided that the provisions in this sub-section shall not apply to the revocation, alteration or variation of a licence issued under section 7A of this Enactment."

Amendment to section 15.

5.(a) Sub-section (ii) of section 15 of the principal Enactment is hereby amended by deleting the word "or" after the words "section 5" and substituting therefor with a comma and by adding after the words "section 7" the words "or section 7A".

(b) Sub-section (iii) of section 15 of the principal Enactment is hereby amended by adding the following proviso thereto:

"Provided that this provision in this sub-section shall not apply in respect of any offence in contravention of section 7A".

Amendment to section 16.

6. Section 16 of the principal Enactment is hereby amended:

(a) by deleting the word "or" after the words "section 5" in sub-section (i) thereof and substituting therefor with a comma and adding after the words "section 7" the words "or section 7A".

(b) by substituting a comma for the full stop at the end of sub-section (ii) thereof and adding thereafter the words "and any pollution in a river to be removed."

(c) by deleting the word "or" after the words "section 5" in sub-section (iii) thereof and substituting therefor with a comma and adding after the words "section 7" the words "or section 7A".

Amendment to section 18.

7. Sub-section (i) (b) of section 18 of the principal Enactment is hereby amended as follows:

(a) insert the words "State Secretaries or" between the words "by" and "District" in line one thereof;

(b) for the word "and" occurring in line three thereof substitute a comma; and

(c) for the semi-colon occurring at the end of the said sub-section substitute the following "and section 7(A):"

Passed this day of ,1970

CLERK OF COUNCILS
(STATE)

APPENDIX D

Process Design Data for Digestion of Clarification Sludge

	Primary					Secondary
	Open R.C. Tank	R.C.Tank with Fixed Roof	+ Gasholder	R.C.Tank with Floating Roof	Earth-Banked Lagoons	Earth-Banked Lagoon
No. of tanks	2	2	1	2	2	1
Size (each)	35 ft.dia. x 25ft.deep	35 ft.dia. x 25 ft.deep	32 ft.dia. x 13ft.9in. deep	35 ft.dia. x 25 ft.deep	40 ft.square x 10ft.deep (sloping walls)	35 ft.square x 10ft.deep (sloping walls)
Capacity (each).(ft.^{3})	24,000	24,000	10,000	24,000	25,000	12,250
Retention (d)	25	25	-	25	26	6.5
Loading (lb.volatile matter/ft.^{3}/d)	0.23	0.23	-	0.23	0.22	-

Estimated Costs

We have considered fixed-roof reinforced concrete primary digesters with and without separate gas collection facilities; floating roof primary digesters with integral gas collection; and simple earth-banked lagoons. We have not considered steel-fabricated tanks in detail but would not expect them to be any cheaper than reinforced concrete tanks. We set out the estimated costs of the alternative schemes below; these estimates include contingencies, supervision and Engineer's fees. We include for an earth-banked secondary lagoon in each scheme. Actual costs could be affected significantly by many local factors, including site location and conditions.

Scheme	Estimated Cost $M
Open R.C. tank	313,000
Fixed-roof R.C.tank without gas collection	322,000
Fixed-roof R.C. tank with separate gas collection	410,000
Floating roof R.C. tank with integral gas collection	469,000
Earth-banked lagoons	299,000

We have not included an item for sludge tankering to land because capital expenditure would be limited to that of a suitable tanker/trailer and possibly a tractor.

APPENDIX E

Process Design Data for

Stabilisation Pond Treatment of Steriliser Condendate

Pond designation refers to Figure No. 5

	A1 & A2	B	C	D	E	F	G
Type of Operation	Anaerobic	Anaerobic	Anaerobic	Anaerobic	Anaerobic	Facultative	Facultative
Area (acres)	0.5 (total)	0.25	0.25	0.125	0.125	0.5	0.5
Depth (feet)	1.0	1.0	1.0	1.0	1.0	3.0	3.0
Retention period excluding recirculation(d)	12	6	6	3	3	36	36
B.O.D. load(lb/d)	2,200	1,100	550	275	138	69	14
B.O.D. loading (lb/acre.d).	4,400	4,400	2,200	2,200	1,100	138	28
B.O.D.removal (%)	50	50	50	50	50	80	85
Effluent B.O.D. (mg/l)	10,000	5,000	2,500	1,250	625	125	19

Recirculation

The minimum ratio of recirculation to influent is usually 1:1. We calculate that a 2 in. pump would enable up to 60 g.p.m. of effluent to be recirculated to the head of the pond system, whilst maintaining reasonable velocities in a 2 in. rising main; thus, the average recirculation ratio would be about 8 : 1. If recirculation to intermediate ponds were also shown to be desirable the availability of this capacity would be useful; if not, a bleed-back from the pumping main to the final effluent line could be used to reduce the recirculation ratio. We show this facility in Figure No. 5.

Estimated Costs

We estimate that the cost of excavating and forming the eight earth-banked ponds, together with appropriate pumping installation and pipework and including contingencies, supervision and Engineer's fees, would be $M116,000. This must be considered as a tentative estimate only which could be affected significantly by many local factors, including site location and conditions.

APPENDIX F

Comments on Unsuitable Treatment Methods

Solids Separation by Gravity

Settlement

We have been given the results of a number of limited settlement tests and have ourselves conducted some simple settlement experiments. We conclude that neither waste is amenable to conventional sedimentation techniques because of the large proportion of finely divided and colloidal solids which are virtually unsettleable in practice. It is possible that long term retention in lagoons would effect significant settlement; we have discussed lagoon treatment in Sections 8 and 9 Even were settlement possible, the limited data available suggest that B.O.D. removal would be minimal. For instance, Kirat Singh et al report: that even after 24 h. sedimentation the upper of two equal layers that formed had a B.O.D. of 15,000 mg/l, compared to the lower layer B.O.D. of 16,000 mg/l; a B.O.D. reduction of only about 3 per cent with a settled sludge volume of about half the original volume.

Flotation

We do not know if the solids in the wastes would be amenable to flotation techniques, but think it unlikely that any worthwhile degree of efficiency could be attained or that experimental work could be justified because of the nature of the solids and high dissolved and colloidal B.O.D.

Centrifugation

We have observed simple experiments where the wastes, separately and mixed, have been centrifuged in the laboratory and limited centrifuge tests have been carried out by the Water Pollution Research Laboratory (Appendix B). In all cases separation of a lower layer of sludge has taken place. It is possible that a degree of separation could be achieved on full-scale, but unlikely that the residue would have a sufficiently low moisture content for convenient handling and the liquid fraction would have a high B.O.D. and fines content. We do not think, therefore, that centrifugation is likely economically or practically to be acceptable even as a partial solution to the problem.

Solids Separation by Filtration

Physical filtration of either waste is likely to be impracticable because any filter medium sufficiently fine to trap the finely-divided solid particles would rapidly blind: this tendency would be aggravated by the oily nature of the solids. The poor filtrability of the centrifuge sludge has been confirmed by the studies carried out on our behalf by the Water Pollution Research Laboratory. In any case, after removal of suspended solids, the filtrate would still have a high B.O.D. and considerable additional treatment would be necessary. We do, however, briefly discuss some filtration techniques and suggest that one of them be examined experimentally.

Rapid Sand Filtration

Rapid sand filtration is applied widely in water treatment practice and for the tertiary treatment of sewage and industrial wastes: upward, downward and radial flow techniques are used with varying degrees of automation and sophistication. The process is most efficient as a means of removing low concentrations of suspended matter from large volumes of water, and therefore would be unsuited to the treatment of palm oil wastes.

Slow Sand Filtration

Rapid sand filtration was developed from this simpler process which essentially relies upon the gravity flow of water through a sand bed. Even when the suspended solids content of the feed is low, large areas of filter are necessary and labour requirements are high: this technique also would be unsuited to palm oil waste treatment.

Sand Drying Beds

Sand drying beds are similar to slow sand filters except that they are designed to convert high-moisture content sludges to a handleable dry sludge cake. The sludge is run onto the bed and dries by drainage and evaporation. Drying beds could be suitable for the dewatering of clarification sludge, but the beds would probably clog rapidly, any drainage would require further treatment and considerable smell nuisance would be likely.

Wedge Wire Drying Beds

Wedge Wire beds would probably be more efficient than sand beds for dewatering clarification sludge and smell problems might be less. However, the finely-divided nature of the suspended solids would be troublesome and large volumes of support water would be required which would increase the problem of liquid effluent disposal.

Screening

It is possible that some of the suspended matter could be removed by ultra-fine screens (e.g. Microstrainers), but the poor B.O.D. removal and mesh-blinding would prevent economical operation.

Upward-flow Clarification

We do not think that this method of treatment is applicable to either of the wastes. The nature of the solids is such that little flocculation could be expected and neither solids nor B.O.D. removal would be significant.

Vacuum Filtration

It is standard practice to condition sludges with appropriate chemicals to improve their filtrability prior to vacuum filtration (dewatering). However, the filtrability studies carried out by

W.P.R.L. using Westfalia clarification sludge (Appendix B) show that the sludge has unusual characteristics and that filtration techniques could not economically be applied to remove and concentrate solids from this waste. Work elsewhere on wastes from other sources confirms this finding and suggests, as would be expected, that neither the condensate nor the mixed effluent is amenable to filtration using existing coagulation and flocculation techniques.

It is possible that filtration through a precoated vacuum filter could be practicable, but we know of no work that has been carried out using this form of treatment. An experimental approach might be useful, and we have discussed this in Section 14 of the Report.

Filter Pressing

The economic viability of pressure filtration is assessed using the same basic parameters as that of vacuum filtration; the system is therefore not practicable for palm oil waste treatment.

Ultra-Filtration

Suspended matter similar to that present in palm oil wastes is sometimes amenable to separation by ultra-filtration techniques. The process is expensive, but if it were shown to be possible technically, might be acceptable, economically as a means of by-product recovery. We have discussed ultra-filtration in Sections 11 and 13 of the Report.

Chemical Treatment

Flocculation

The efficiency of settlement can often be increased considerably by adding chemical coagulants to a waste and allowing flocculation to take place either in a specially designed flocculator or in the settlement tank itself. Flocculation sometimes can be achieved even without the use of chemicals, in, for example, a picket-fence flocculator. Work on palm oil wastes by Kirat Singh et al, W.P.R.L. and others suggests that flocculation would have little effect with palm oil waste unless, perhaps, massive chemical doses were used.

Oxidation

The pollutional effects of palm oil wastes could be reduced by chemical oxidation with, for example, chlorine or ozone and it is possible that the filtrability of the suspended solids would be improved attendantly. However, the production of volumes of either gas sufficient fully to oxidise the wastes would be prohibitively expensive. Theoretically, electrolytic treatment could be effective in coastal areas where sea water would be readily available, but the cost of electricity would be high.

Heat Treatment

Low Pressure

We have discussed the problem of conditioning the clarification sludge chemically in order to render it more amenable to physical dewatering processes. It is possible that the use of heat treatment techniques could prove more successful. Heat treatment involves the application of heat to the sludge under low pressure and is used successfully to condition sewage sludges; these are, however, more amenable to chemical conditioning. Experimental work would be necessary before the process could be considered for palm oil waste, but the cost of the process is high and we do not think that the initiation of experimental work could be justified.

High Pressure

The mixed wastes, or either waste separately, could be treated by the wet oxidation process. In this process the waste is subjected to increased temperature and pressure (120 - 300°C and 150 - 1,500 p.s.i. respectively) and the organic constituents are oxidised, resulting in an inert and readily settleable solids fraction; this may be separated from a liquid fraction which has a comparatively low B.O.D. We think that this process would be applicable to palm oil wastes but unattractive economically.

Incineration and Evaporation

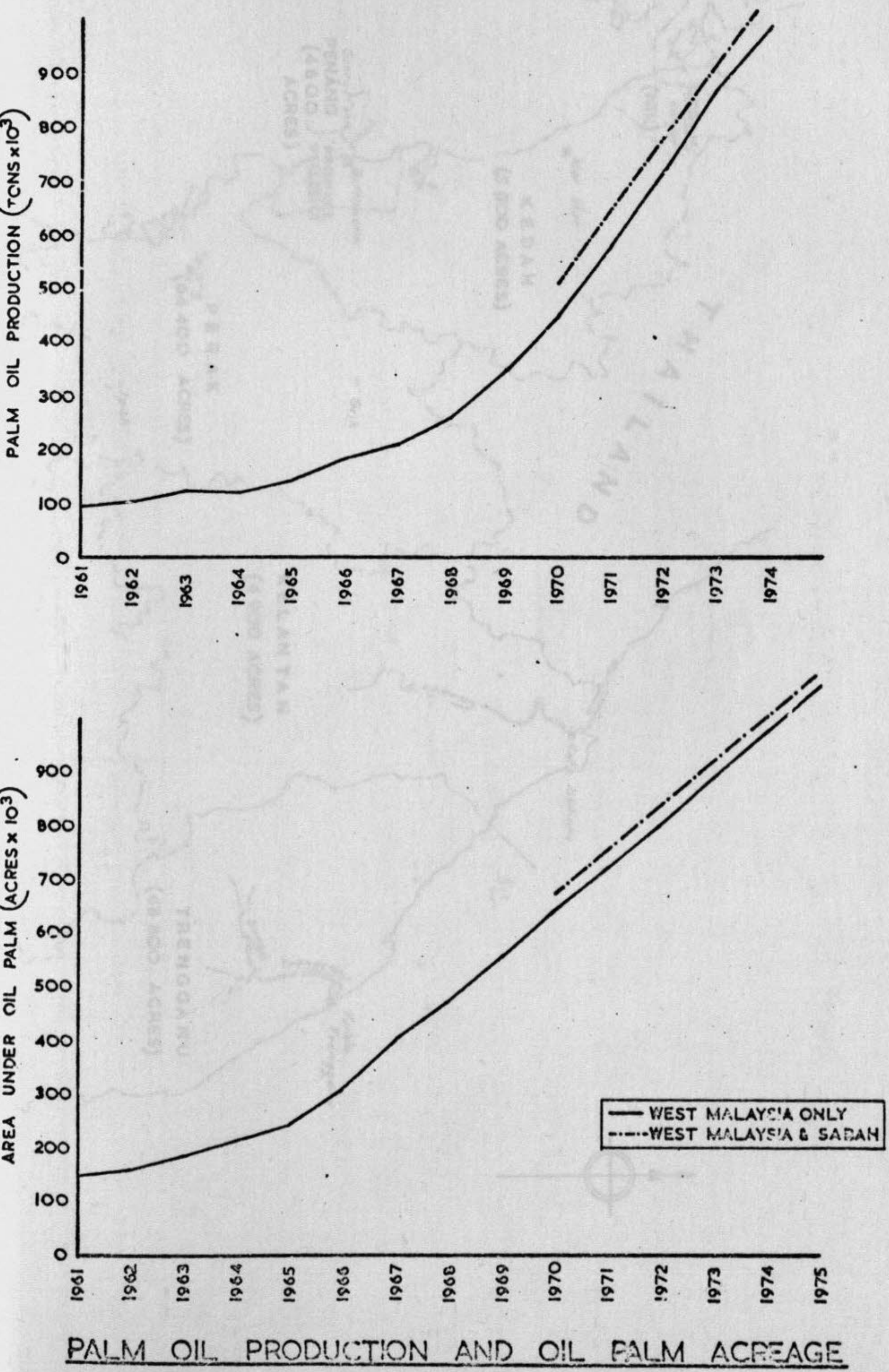
Incineration

Incineration is costly and it would in any case be preferable to dewater the wastes prior to introducing them to an incinerator. The process is attractive in that it produces comparatively small volumes of a sterile and easily handleable ash, but the effluent from any preliminary dewatering process would require further treatment and the added cost of this and of the dewatering plant itself would result in very high overall treatment costs.

Evaporation

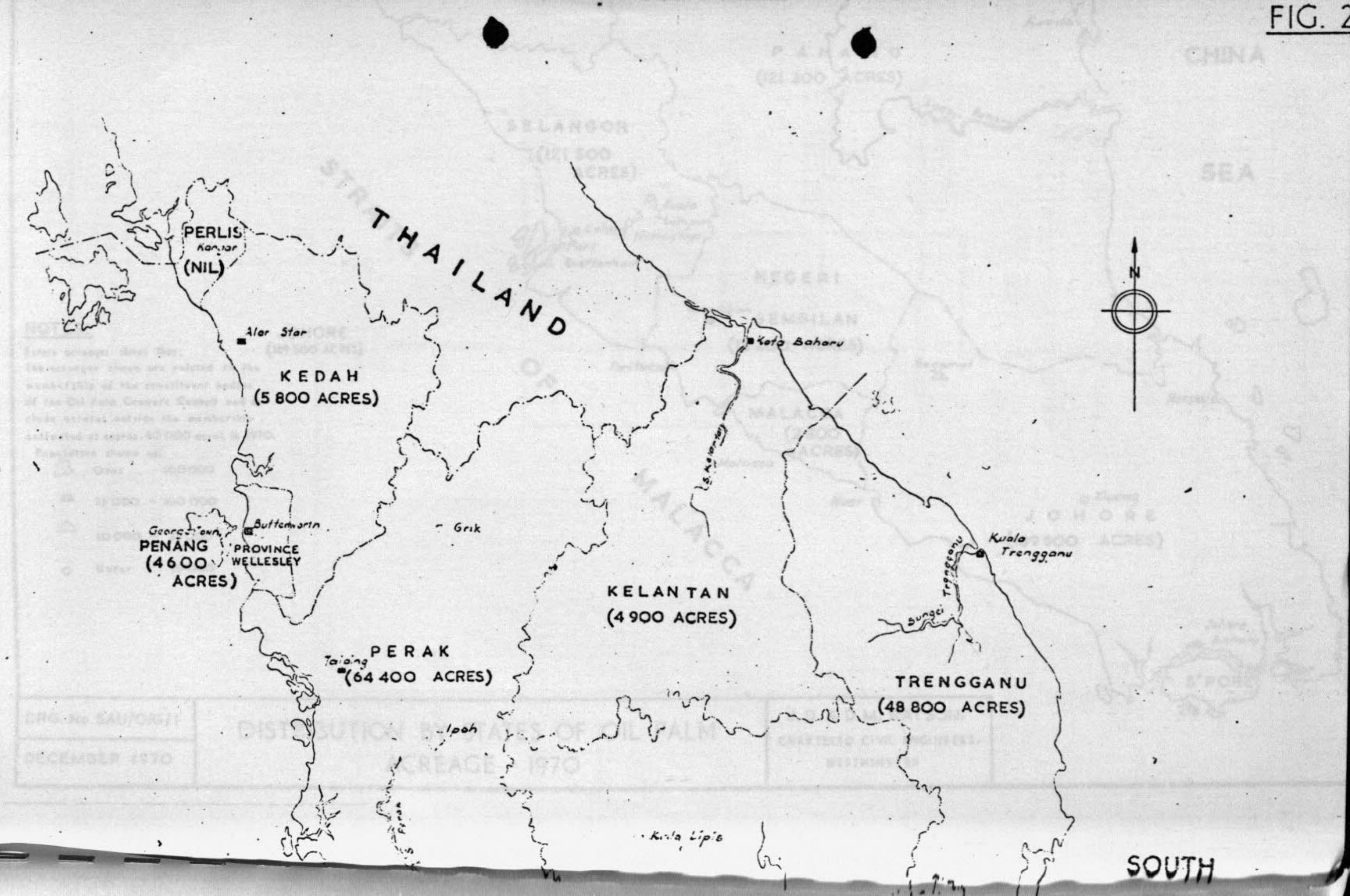
The comparatively low solids content of the condensate militates against evaporation as an economical treatment process and we have also shown the cost of evaporation of clarification sludge to be high (Section 11).

FIG. I.



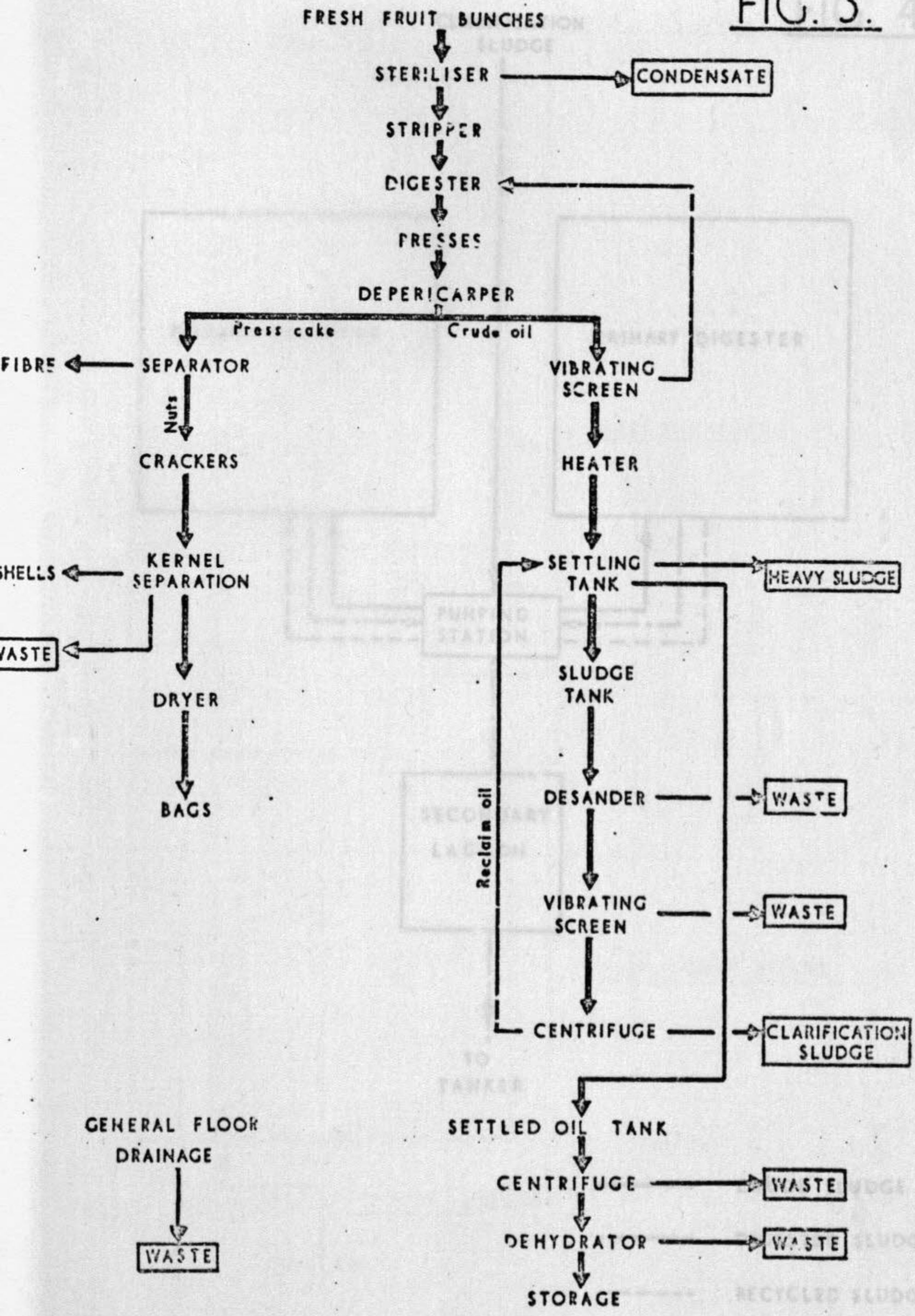
PALM OIL PRODUCTION AND OIL PALM ACREAGE

FIG. 2


THAILAND
PERLIS
Kangar
(NIL)
Alor Star
KEDAH
(5 800 ACRES)
Butterworth
George Town
PENANG
(4600 ACRES)
PROVINCE WELLESLEY
Grik
Taiping
PERAK
(64 400 ACRES)
Ipoh
Kota Baharu
S. Kelantan
KELANTAN
(4 900 ACRES)
Kuala Trengganu
Sungei Trengganu
TRENGGANU
(48 800 ACRES)
Kuala Lipis
N
SOUTH

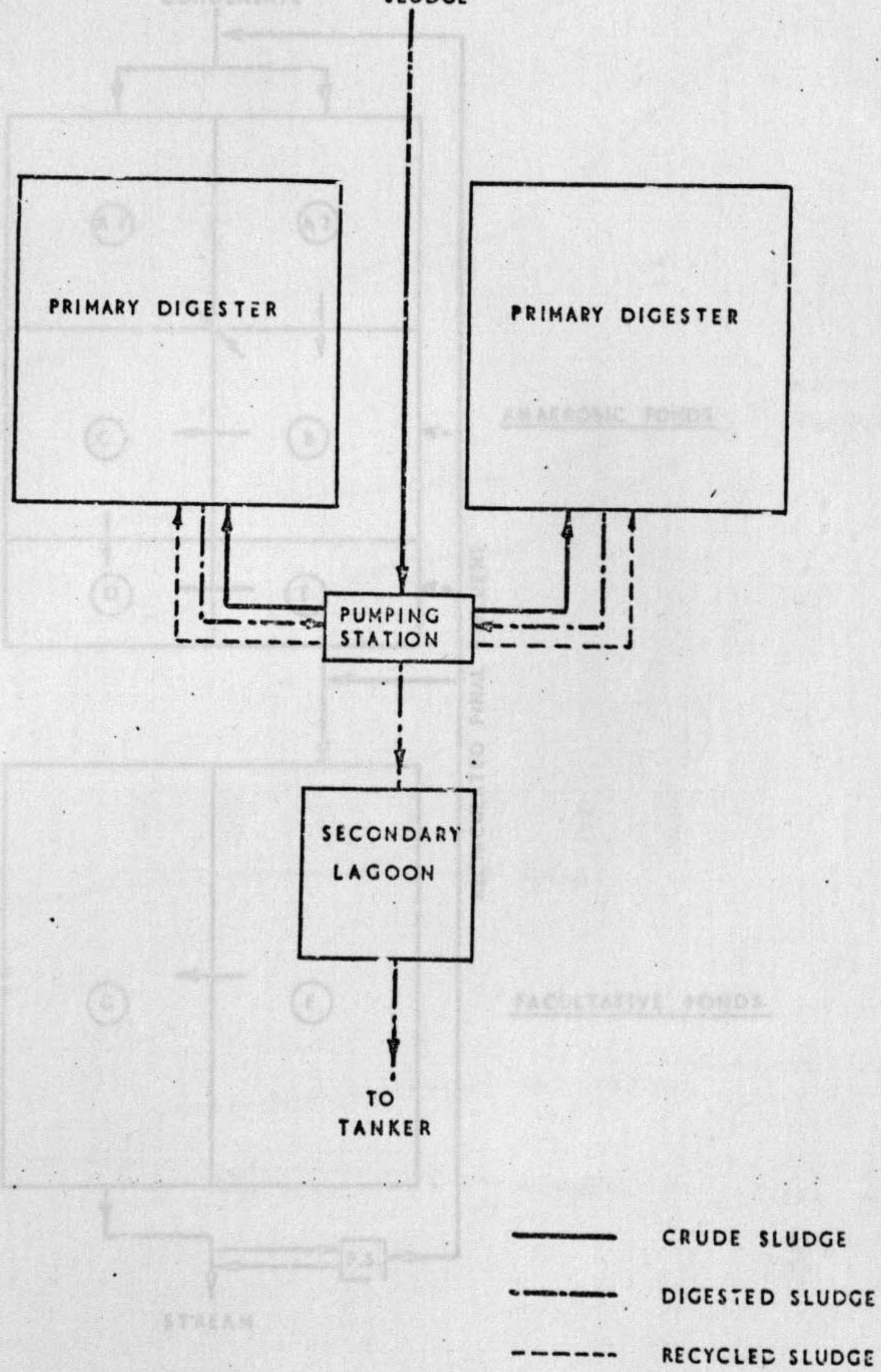
DRG. No. SAU/O/G/1	DISTRIBUTION BY STATES OF OIL PALM ACREAGE - 1970	J. D. & D.M. WATSON, CHARTERED CIVIL ENGINEERS, WESTMINSTER
DECEMBER 1970		

FIG. 3.



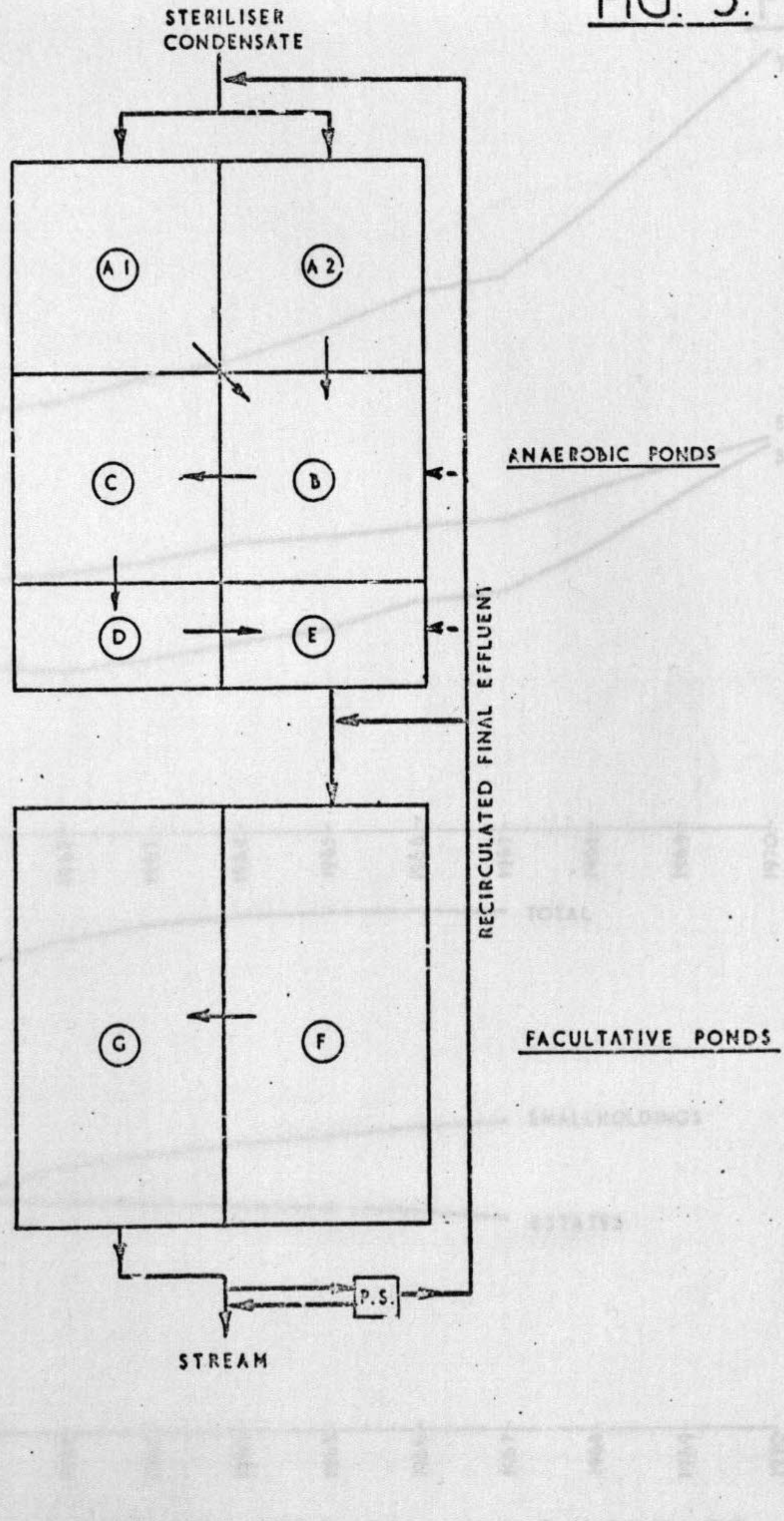
PALM OIL MILL - GENERALISED FLOW DIAGRAM SHOWING PROCESSES MOST COMMONLY IN USE AND SOURCES OF WASTES

FIG. 4.



CLARIFICATION SLUDGE DIGESTION PLANT FLOW DIAGRAM

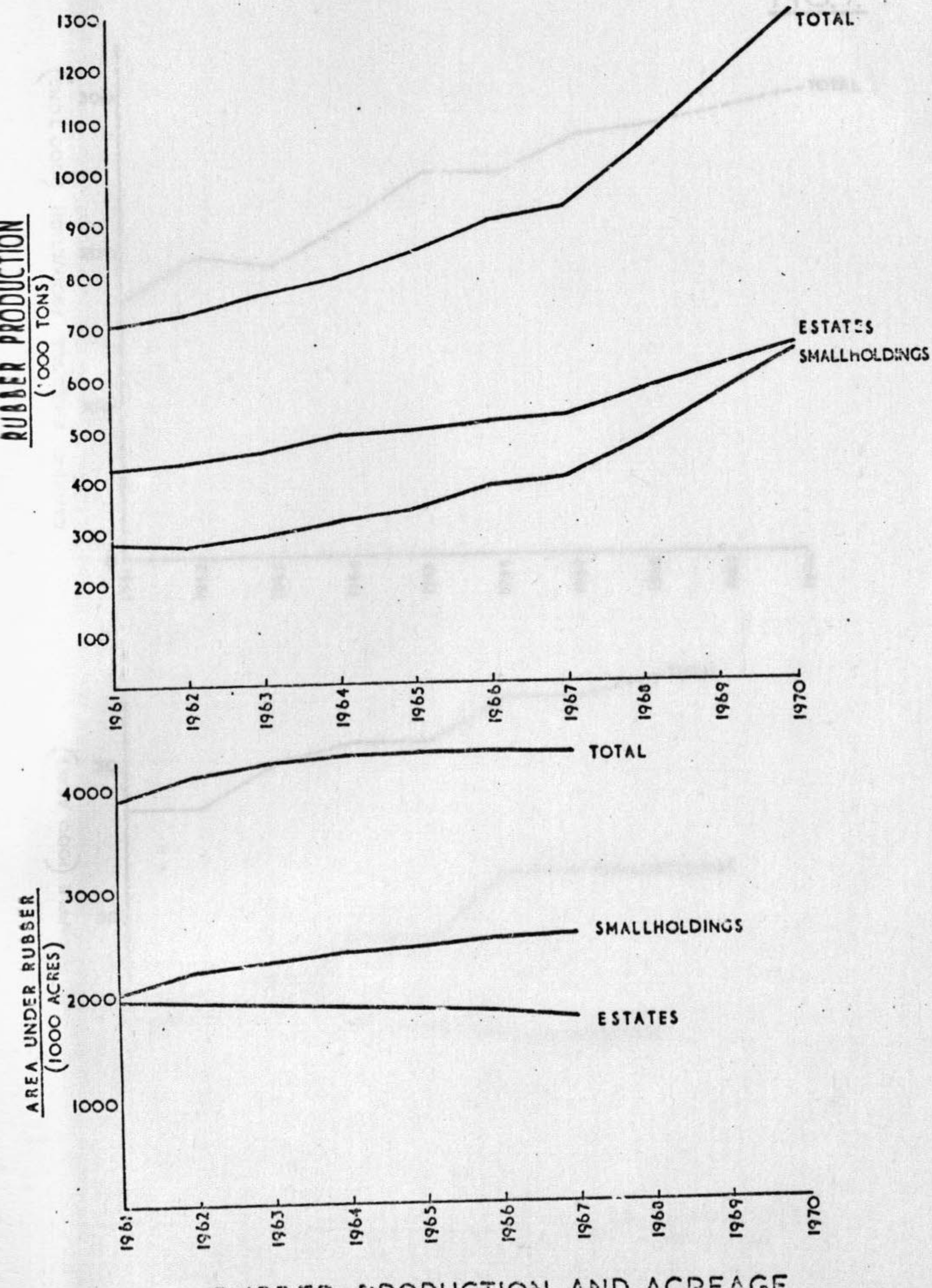
FIG. 5.



STERILISER CONDENSATE STABILISATION POND

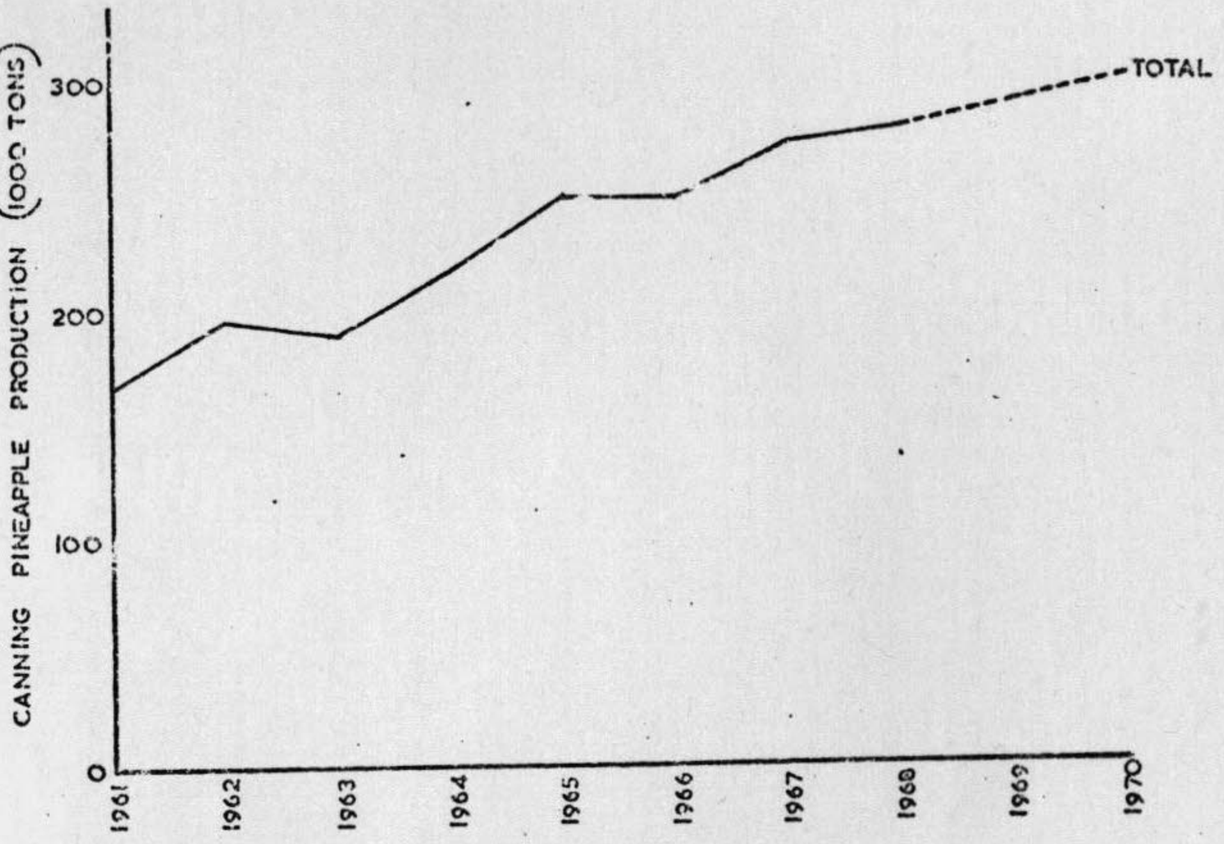
FLOW DIAGRAM

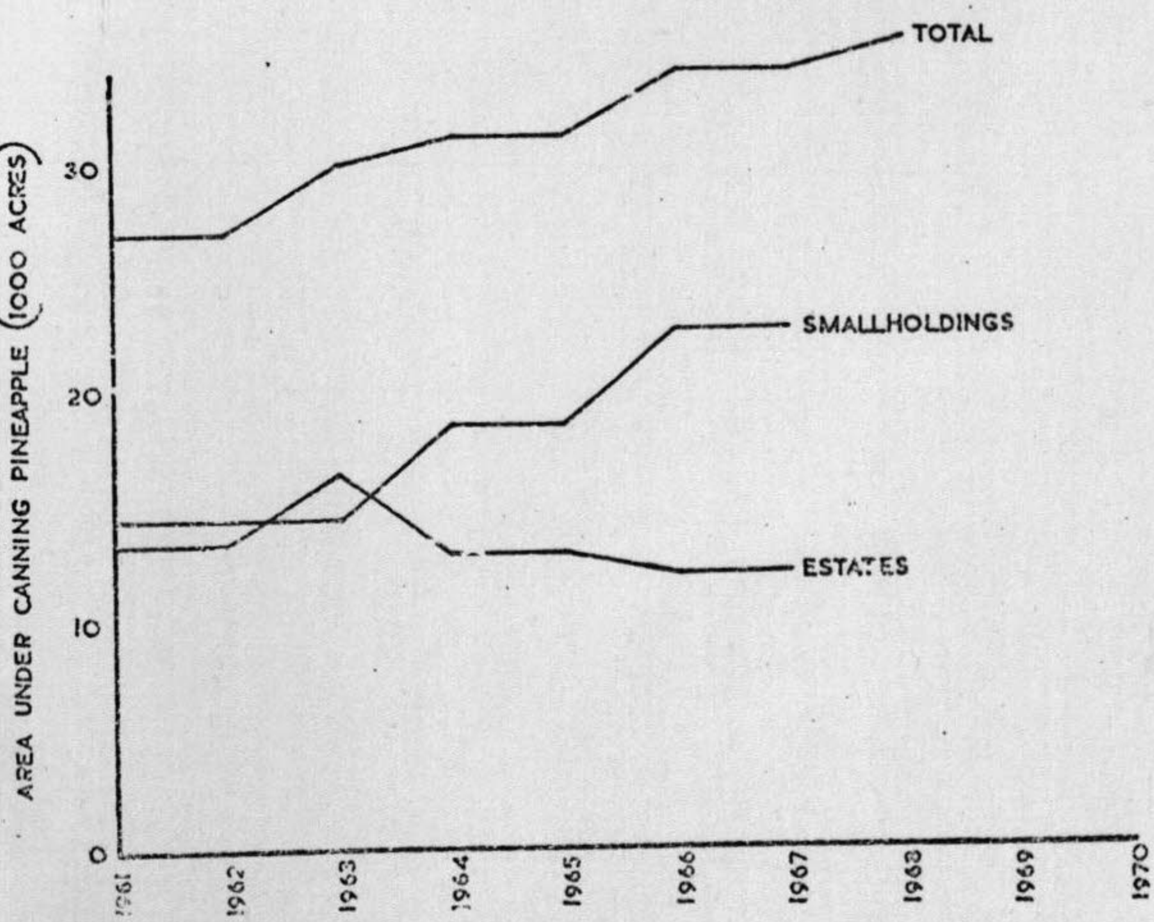
FIG. 6.



RUBBER PRODUCTION AND ACREAGE

FIG. 7.





CANNING PINEAPPLE PRODUCTION AND ACREAGE