

Monitoring the Long Term Effects of Land Application of Palm Oil Mill Effluent to Oil Palm on Water Quality

Hamdan, A B*; Mohd Tayeb, D*;
Zin Zawawi, Z*; Ahmad Tarmizi, M* and Khalid, H*

ABSTRACT

The benefits of irrigating digested palm oil mill effluent (POME) in oil palm plantations have been reported by several researchers. POME, which contains water and high nutrient, can improve yield and is suitable for palm growth. However, it needs proper and efficient management to ensure clean and safe water sources. The paper reports the effects of applying digested-POME in an oil palm plantation on the water quality in the surrounding area.

MPOB had conducted a long term monitoring work over 13 years to study the effects of irrigating digested-POME in an oil palm plantation as a source of nutrients on the water quality. The results from site monitoring using stream water and tube well showed that proper application of POME at a controlled rate did not pollute the water sources. Applying digested-POME at the rate of 6.0 cm rain equivalent per year (r.e.y) into the field every three to four months was suitable and recommended. Irrigating too high a volume, i.e. over 2.5 cm r.e.y. per application should not be practiced to avoid anaerobic conditions. Accumulation of heavy metals such as Mn, Fe, Cu, Zn, Pb and Cd in the water sources appeared to be negligible. This study also indicated that the strong soil retention of heavy metals and uptake of mineral nutrients by the palms naturally could control water pollution effectively.

ABSTRAK

Faedah penggunaan effluen kilang sawit (POME) di ladang sawit telah banyak dilaporkan oleh para penyelidik kerana sifat-sifatnya kaya dengan unsur-unsur pemakanan yang sesuai untuk pertumbuhan dan penghasilan pokok. Bagaimanapun, bahan sisa buangan ini memerlukan pengurusan yang

sempurna dan cekap memandangkan ia berpotensi mencemar alam sekitar terutama terhadap sumber-sumber air.

MPOB telah menjalankan satu kajian jangka panjang selama 13 tahun mengenai kesan perlepasan POME ke ladang sawit sebagai kaedah perlupusan sisa di samping digunakan sebagai input baja di ladang, terhadap kualiti sumber air di kawasan persekitaran. Hasil penilaian tersebut menunjukkan penggunaan effluen yang dirawat (treated-POME) dengan pengurusan baik pada kadar dan kekerapan yang terkawal tidak mencemarkan sumber air-permukaan dan juga sumber air bawah-tanah. Pengumpulan unsur-unsur logam berat seperti Mn, Fe, Cu, Zn, Pb dan Cd di dalam sumber air, kesan daripada penggunaan effluen kilang sawit yang berulang-ulang juga didapati minimum atau boleh diabaikan. Penilaian ini menunjukkan bahawa tanah berfungsi sebagai pengawal pencemaran yang berkesan.

Daripada penilaian ini, penggunaan POME pada kadar 6.0 cm hujan sehektar setahun (r.e.y) yang disalurkan ke ladang adalah didapati sesuai dicadangkan. Kuantiti tersebut dilepaskan ke ladang setiap tiga hingga empat bulan sekali atau lebih kerap dengan jumlah yang sama banyak setiap ulangan. Penggunaan pada kadar yang berlebihan pada satu-satu masa perlu dikawal iaitu tidak melebihi 2.5 r.e.y., bagi mengelakkan berlaku keadaan tergenang (anaerobic) yang boleh mengganggu pertumbuhan dan penghasilan pokok sawit.

INTRODUCTION

The Malaysian oil palm industry continued to be on an upswing with the total oil palm area reaching almost 3.31 million hectares. In line with this, 336 mills approved by the Palm Oil

* Malaysian Palm Oil Board, P.O. Box 10620, 50720 Kuala Lumpur, Malaysia.

Registration and Licensing Authority (PORLA) were in operation in 1999. These mills generated a large volume of palm oil mill effluent (POME) totalling about 24.7 million tonnes per year.

At the same time, more restrictions are being imposed on the mills to reduce their contamination of land, water and air, requiring greater efficiency and sanitation in the collection, treatment and disposal of wastes.

POME is one of the major by-products released from an oil palm mill. A mill with a processing capacity of 60 t fresh fruit bunches (FFB) hr^{-1} can generate about 193 000 t of POME annually. Discharging the raw-POME directly into waterways is a threat to the environment because of the high biological oxygen demand (BOD) and chemical oxygen demand (COD) contents (Yeow and Gurmit, 1983).

Treated or digested-POME instead of the raw waste material has been used as a nutrient source in oil palm plantations. The application of POME significantly improved some of the soil chemical properties (Lim *et al.*, 1983; Tan, 1983; Lim, 1987; Mohd Hashim, 1991; Lim *et al.*, 1991). It also had beneficial effects on FFB yield and yield components (Lim, 1987; Mohd Tayeb *et al.*, 1987; Lim *et al.*, 1991). It is being increasingly recycled to the plantations as a valuable source of organic fertilizer.

However, due to its tremendous volume and polluting potential, the POME that is generated requires proper management and handling by the industry and government authorities. With the increasing trend towards increased and continuous application of POME onto land, there is a need to assess its impact on the environment, especially on water sources, both on a short as well as long term basis.

When POME is applied onto land, the organic and inorganic constituents it contains may be retained by the soil, taken up by the palms, leached through the soil or washed by surface runoff. There is a need to monitor the subsurface water quality in land application of POME schemes to ensure that the regulatory standards are being met, and to observe the suitability of design of the application and also to provide information. This paper reports the results obtained from MPOB's long term monitoring activity on surface and groundwater quality in a land application of digested-POME scheme carried out over the years in a commercial oil palm plantation.

MATERIALS AND METHODS

This monitoring activity was initiated in 1985, two years after the land application of POME. This project was carried out in C.E.P Rengam Estate, Kluang, Johor. The trial site was on gently sloping land with a gradient of about 15% – 20 %. The soil was mainly Rengam series (sandy clay, Typic Paleudult, Ultisol). The mean total rainfall of this area was about 1834 mm yr^{-1} with an average of 10 rainy days per month (*Appendices 1a* and *1b*). The palms of this area were planted in 1967. The flatbed system of POME application was used having dimensions of 2.5 m x 2.5 m and 0.20 m depth constructed on alternate palm rows (*Figure 1*). The flatbeds along a slope were interconnected with channels. During application, effluent was pumped up to the topmost flatbed and allowed to flow down by gravity. As the bottommost flatbed was filled to the required height, the interconnecting channel was sealed off with soil and the next lowest flatbed was then filled up accordingly. Treated (tank-digested) POME was continuously applied at 6.0 cm r.e.y to a field near the mill in four applications annually.

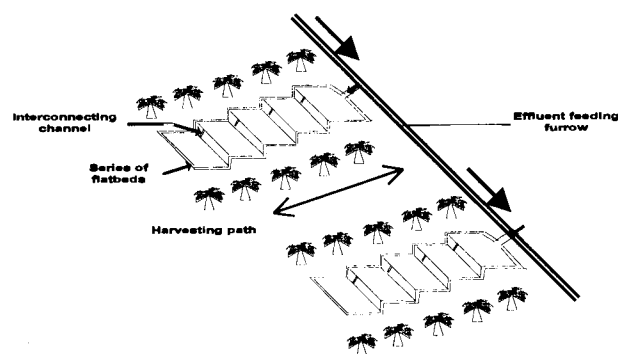


Figure 1. Diagrammatic representation of the flatbed system.

Samples of raw- and tank-digested effluent, surface water from two streams running in the lower part of the trial area at three different sites [before discharge (control), at discharge, after discharge points] and the groundwater in three replicates at each site were collected. The samples were taken and analysed monthly. A simple technique was adopted in the monitoring of groundwater. This involved the placement of PVC tubes (3.8 cm diameter) inserted vertically into the soil augered to about 3.0 m depth, *i.e.* below the permanent water table. These pipes were located in a number of spots within the POME applied area at varying distances. Lately, as suggested by the PORIM's

Programme Advisory Committee (PAC) members in 1997, samples of groundwater from the adjacent area, located about 400 to 500 m away from the treated area, were also monitored as control.

RESULTS AND DISCUSSION

The chemical compositions of raw- and digested-POME from 13-year analyses are shown in *Tables 1* and *2*. The analyses indicate a wide variation in their contents for both types of POME. Seasonal and locational differences in which the samples were collected probably resulted in the variation in concentration for most of the parameters analysed.

Raw-POME was generally acidic in nature with pH ranging from 3.9-5.8 while the digested-POME had a very significantly higher pH values ranging from 6.0-8.1. Other workers (Lim *et al.*, 1983; Zin *et al.*, 1983; Mohd Hashim, 1991) also reported similar results. The overall means of the 13-year period (1984 – 1997) were 4.7 and 7.3 respectively. Within the confines of the monitoring period, the application of digested-POME onto the field did not produce significant changes in the pH of the surface and groundwater in the area (*Tables 3a* and *3c*).

Raw-effluent contains relatively high amounts of plant nutrients, particularly potassium (K), nitrogen (N), magnesium (Mg) and calcium (Ca), but is quite low in phosphorus (P) as shown in *Table 1*. The results also showed that lower levels of nutrients were observed in the digested-POME, especially N, NO_3^- , P and Mg but higher NH_4^+ , K and Ca compared to the raw- POME. These results were also reported by other workers (Lim *et al.*, 1983; Tan, 1983; Zin *et al.*, 1983; Khalid and Zin, 1994; Zin *et al.*, 1995). The differences between the raw- and digested-POME in terms of their nutrient contents were not significant except for N.

Nitrate (NO_3^-), an important ion in plant nutrition, is also considered a significant environmental pollution indicator. It is deemed to be undesirable because of its potential role in (a) eutrophication, (b) infant methemoglobinemia associated with the consumption of nitrate-rich water or vegetable, (c) animal methemoglobinemia, and (d) the formation of nitrosamines (Alexander, 1977). The World Health Organization (WHO) and various countries have established standards for the quality of water designed for human

consumption. The standard is 10 mg litre⁻¹ nitrate-N, a level below which clinical methemoglobinemia in infants is extremely rare. The interim water quality standards adopted by the Department of Environment (DOE), Malaysia are 7 mg litre⁻¹ and 10 mg litre⁻¹ for surface water and groundwater respectively (*Appendices 2* and *3*).

As shown in *Table 1*, the NO_3^- contents of the raw- and treated-POME were rather high. The mean NO_3^- levels in raw- and digested-POME were 252 mg litre⁻¹ and 103 mg litre⁻¹, respectively. However, over the 13-year continuous application of digested-POME to the field, the NO_3^- content in surface water was relatively low. The mean NO_3^- concentrations in surface water taken from the three monitoring points (before, at and after discharge points) were 4.75, 4.22 and 3.88 mg litre⁻¹, respectively (*Table 3a*). These levels complied with the DOE's standard of 7 mg litre⁻¹ maximum. The results also showed that the difference in NO_3^- levels at different collecting points was not statistically significant. The mean NO_3^- level analysed in the groundwater was 13.3 mg litre⁻¹ (*Table 3b*), slightly above the DOE's standard of 10 mg litre⁻¹. Referring to the DOE, this level was however considered marginal. In addition, analysis of the samples taken in 1997 showed that the difference in NO_3^- content between the applied and non-applied (adjacent) area was not statistically different (*Table 3c*).

The P was comparatively low and the least mobile element among the nutrients analysed. Phosphate, in contrast to nitrate, reacts with the soil components to form insoluble compounds that are immobile in soils. For this reason, there was little possibility of the surface water becoming polluted from the use of POME. This can clearly be seen from the data collected in *Table 3a*. Over the years of application of POME, the P levels in the groundwater were low with an exception for the samples taken in 1997 (*Tables 3a*, *3b* and *3c*).

There are many similarities between the behaviour of K, Mg and Ca in soils. Out of these, K is among the most important fertilizer element and generally not considered an environmental hazard, as it is harmless to higher life. The K and Mg which are the more mobile elements and are generally in the ionic state in tissues (Yawalkar *et al.*, 1977), probably leached out of the tissues during the harsh processing of the fruit bunches (Palaniappan *et al.*, 1983). This would account for the high levels of K and Mg in

TABLE 1. NUTRIENT CONTENTS AND pH VALUE OF RAW- AND DIGESTED-POME AT THE MONITORING SITE (1985 - 1997)

Description of samples	Year	N (mg litre ⁻¹)	NO ₃ ⁻ (mg litre ⁻¹)	NH ₄ ⁺ (mg litre ⁻¹)	P (mg litre ⁻¹)	K (mg litre ⁻¹)	Ca (mg litre ⁻¹)	Mg (mg litre ⁻¹)	pH
Raw-POME	1985	293	38	21	15	426	67	160	5.2
	1986	597	319	27	38	1 445	175	289	3.9
	1987	612	885	29	37	1 406	202	290	4.4
	1988	769	438	50	48	1 590	333	350	4.1
	1989	692	360	62	39	1 777	241	383	4.3
	1990	599	424	35	25	1 523	467	224	4.7
	1991	683	235	111	29	2 589	170	309	5.0
	1992	797	278	57	39	2 409	247	601	4.7
	1993	718	5	37	83	1 377	310	356	4.4
	1994	1 036	92	49	34	2 216	127	362	5.4
	1995	283	53	100	40	3 789	231	297	5.8
	1996	123	120	65	31	1 503	146	241	5.0
	1997	256	76	72	59	1 469	136	128	4.7
Digested-POME	1985	172	63	61	15	645	48	179	7.4
	1986	436	66	147	53	1 587	312	296	6.9
	1987	570	107	162	50	1 313	564	306	7.3
	1988	502	81	134	38	1 636	309	316	7.0
	1989	526	84	94	48	1 832	273	374	7.1
	1990	445	91	198	19	1 502	544	221	7.3
	1991	346	60	54	18	2 139	190	367	7.6
	1992	421	152	107	21	2 109	239	523	6.8
	1993	196	2	49	23	1 312	198	305	7.8
	1994	183	67	121	9	5 383	84	254	8.1
	1995	235	221	27	67	4 543	298	343	6.0
	1996	64	135	48	4	1 394	79	219	8.1
	1997	93	211	36	7	1 546	78	117	7.1
Raw-POME	n	13	13	13	13	13	13	13	13
	Min.	123	5	21	15	426	67	128	3.9
	Max.	1 036	885	111	83	3 789	467	601	5.8
	Mean	574	252	55	40	1 809	219	307	4.7
	S.E.	72.4	67.1	7.64	4.65	223.4	32.5	0.15	
Digested-POME	n	13	13	13	13	13	13	13	13
	Min.	64	2	27	4	645	48	117	6.0
	Max.	570	221	198	67	5 383	564	523	8.1
	Mean	322	103	95	29	2 072	247	294	7.3
	S.E.	47.9	17.2	15.07	5.62	373.9	45.9	28.2	0.16
Paired t-test	Difference	251.5	152.5	-40.2	11.2	-263.0	-28.0	13.1	-2.5
	value with 12 d.f.	3.96	2.16	-1.97	1.57	175	-0.84	1.01	-11.6
		**	ns	ns	ns	ns	ns	ns	***

Notes:

n - number of sample means.

S.E. - standard error.

ns - not significant.

** significant at the 1% level.

*** significant at the 0.1% level.

the water soluble state in POME (Table 1). When the effluent was applied to the land, this element was rapidly absorbed by the soil colloids, held in the soil solution or taken up by the palms. The K and Mg levels were found very much reduced either in the surface water or in the groundwater (Tables 3a, 3b and 3c). We also noticed that the K content in the groundwater from the effluent applied area was significantly higher (t

= 5.63, df = 21, p < 0.0001) than from the adjacent area applied with fertilizer (Table 3c).

Mg and Ca are also important elements after N, P and K. Even though the Mg and Ca contents in effluent are relatively high, they did not affect the water quality very much. From the analysis, it was shown that Ca was significantly higher (t = 8.21, df = 21, p < 0.0001) in the

TABLE 2. HEAVY METAL CONTENTS OF RAW- AND DIGESTED-POME AT THE MONITORING SITE (1985 - 1997)

Description of samples	Year	Mn (mg litre ⁻¹)	Fe (mg litre ⁻¹)	Cu (mg litre ⁻¹)	Zn (mg litre ⁻¹)	Pb (mg litre ⁻¹)	B (mg litre ⁻¹)	Cd (mg litre ⁻¹)
Raw-POME	1985	0.38	37.88	0.75	1.32	0.00	0.46	n.d
	1986	1.76	44.40	0.76	1.23	0.00	1.00	n.d
	1987	3.12	53.66	0.88	1.28	0.00	1.08	n.d
	1988	4.70	66.27	0.71	1.48	0.00	0.92	n.d
	1989	3.44	55.70	0.37	1.42	0.00	0.81	n.d
	1990	1.41	52.01	0.46	3.56	0.00	1.15	n.d
	1991	1.38	38.40	0.56	0.60	0.04	1.00	n.d
	1992	2.80	77.40	0.71	1.76	0.09	1.45	n.d
	1993	2.62	47.40	0.76	1.26	0.17	1.22	n.d
	1994	2.23	40.60	0.54	0.93	0.38	0.50	n.d
	1995	0.00	83.00	0.00	0.00	0.00	2.60	n.d
	1996	0.00	100.10	0.00	0.00	0.00	2.67	n.d
1997	1.00	39.45	0.87	1.30	0.00	4.00	n.d	
Digested- POME	1985	0.44	13.72	0.13	0.63	0.00	0.72	n.d
	1986	2.61	43.76	0.90	1.99	0.00	1.54	n.d
	1987	3.00	38.23	1.05	1.49	0.00	0.97	n.d
	1988	2.72	41.99	0.60	0.96	0.00	0.67	n.d
	1989	2.56	44.14	0.87	1.20	0.00	0.52	n.d
	1990	0.99	32.57	0.23	1.00	0.00	0.75	n.d
	1991	1.46	44.96	0.57	0.86	0.01	0.89	n.d
	1992	0.80	15.40	0.63	0.72	0.12	1.00	n.d
	1993	0.97	24.90	0.35	0.50	0.19	0.78	n.d
	1994	0.38	13.98	0.37	0.10	0.32	0.34	n.d
	1995	0.00	27.50	0.00	0.00	0.00	1.60	n.d
	1996	0.00	16.30	0.00	0.00	0.00	1.62	n.d
1997	3.07	50.10	1.63	2.31	0.00	2.00	n.d	
Raw-POME	n	13	13	13	13	13	13	13
	Min.	0.00	37.88	0.00	0.00	0.00	0.46	n.d.
	Max.	4.70	100.10	0.88	3.56	0.38	4.00	n.d
	Mean	1.91	56.60	0.567	1.24	0.05	1.45	n.d.
	S.E.	0.392	5.44	0.081	0.245	0.031	0.284	-
Digested-POME	n	13	13	13	13	13	13	13
	Min.	0.00	13.70	0.00	0.00	0.00	0.34	n.d
	Max.	3.07	50.10	1.63	2.31	0.32	2.00	n.d
	Mean	1.46	31.40	0.564	0.91	0.05	1.03	n.d
	S.E.	0.325	3.73	0.129	0.199	0.028	0.139	-
Paired t-test	Difference	0.45	25.20	0.003	0.34	0.003	0.42	-
	T value with 12 d.f.	1.34	3.34	0.03	1.34	0.51	2.36	-
		ns	**	ns	ns	ns	*	-

Notes:

n - number of sample means.

S.E. - standard error.

ns - not significant.

* significant at the 5% level.

** significant at the 1% level.

n.d - non-detectable.

POME applied area compared to the adjacent area. The same case was also observed for Mg, i.e., $t = 7.04$, $df = 21$, $p < 0.0001$ (Table 3c).

EFFECTS OF POME ON HEAVY METALS

Table 2 shows the mean concentrations of heavy metals in raw- and treated-POME. Generally, manganese (Mn), copper (Cu), zinc (Zn), lead (Pb) and boron (B) were present in small quantities in raw and even lower levels in

digested-effluent. Iron (Fe), however, was present in relatively high amounts in raw-POME but was significantly lower in treated-POME. Cadmium (Cd) was non-detectable in both raw- and treated-effluent.

The analyses of heavy metals (Table 4a) showed that the effects of POME application on surface water quality appeared minimal or negligible. Most of the heavy metal concentrations in the surface water compiled with the DOE standards (Table 5). The mean

TABLE 3a. THIRTEEN-YEAR EFFECTS OF POME APPLICATION ON NUTRIENT CONTENTS AND pH VALUE OF SURFACE WATER AT THE MONITORING SITE, C.E.P. RENGAM ESTATE, KLUANG, JOHOR

Description of samples	Year	N (mg litre ⁻¹)	NO ₃ ⁻ (mg litre ⁻¹)	NH ₄ ⁺ (mg litre ⁻¹)	P (mg litre ⁻¹)	K (mg litre ⁻¹)	Ca (mg litre ⁻¹)	Mg (mg litre ⁻¹)	pH
Stream water - before discharge point	1985	4.7	1.4	4.7	0.0	1.4	3.3	1.2	5.4
	1986	1.6	0.5	2.0	0.0	5.6	14.7	2.1	5.2
	1987	4.3	0.8	2.5	0.0	3.7	9.5	3.0	4.7
	1988	2.6	0.3	2.9	0.0	1.8	17.0	1.6	5.2
	1989	3.3	0.3	1.7	0.0	3.4	16.4	1.2	5.2
	1990	0.6	0.2	0.2	0.0	3.6	1.6	0.0	5.8
	1991	1.7	5.5	5.5	0.0	8.3	1.9	0.0	5.5
	1992	2.4	2.1	0.2	0.0	0.0	6.1	2.8	5.5
	1993	8.6	0.3	0.0	0.0	1.7	8.6	1.1	4.6
	1994	9.1	4.1	3.7	0.0	71.3	5.7	0.3	5.1
	1995	13.0	24.6	15.4	0.0	72.0	30.0	14.0	5.5
	1996	24.4	10.6	13.8	0.0	30.5	10.8	1.5	5.7
	1997	40.5	11.1	17.1	0.0	38.2	2.2	2.1	5.0
Stream water - at discharge point	1985	5.0	0.1	5.3	0.0	1.3	2.7	1.6	5.6
	1986	1.5	0.1	1.8	0.0	2.6	12.7	6.7	5.2
	1987	2.7	0.5	2.4	0.0	3.3	9.3	3.3	4.7
	1988	2.6	0.3	2.8	0.0	0.5	23.5	2.2	5.2
	1989	1.7	0.9	1.2	0.0	5.3	16.5	3.2	5.1
	1990	0.6	0.2	0.2	0.0	1.4	2.4	0.0	6.1
	1991	1.8	0.8	0.4	0.0	1.7	1.8	0.1	5.7
	1992	3.1	1.9	0.0	0.0	1.1	6.5	1.8	5.5
	1993	8.8	5.4	0.1	0.0	2.5	8.3	1.1	4.5
	1994	9.2	3.5	3.2	0.0	79.6	5.6	0.4	4.8
	1995	15.0	21.3	16.8	0.0	68.0	29.0	16.1	5.2
	1996	22.4	9.8	13.5	0.0	30.0	10.7	1.6	6.0
	1997	34.5	10.0	17.2	0.0	34.9	2.4	1.8	5.4
Stream water - after discharge point	1985	0.0	0.1	4.4	0.0	0.0	0.0	0.0	5.6
	1986	1.7	0.7	1.5	0.0	2.9	12.8	2.6	5.2
	1987	2.7	0.6	2.5	0.0	2.5	11.1	2.0	4.8
	1988	2.3	0.3	2.7	0.0	0.4	24.8	1.2	5.1
	1989	1.3	0.4	1.0	0.0	6.3	22.4	0.9	5.2
	1990	0.3	0.4	0.1	0.0	0.7	2.8	0.0	5.9
	1991	0.8	1.2	0.1	0.0	2.2	1.6	0.1	6.0
	1992	3.0	1.6	0.0	0.0	1.1	5.6	2.8	5.6
	1993	8.8	0.4	0.1	0.0	2.7	9.7	1.0	4.6
	1994	10.4	2.5	3.7	0.0	77.2	6.2	1.5	4.9
	1995	14.0	17.3	21.0	0.0	64.0	29.0	16.0	5.3
	1996	27.4	7.2	14.0	0.0	31.3	11.7	1.7	6.0
	1997	46.9	17.7	17.8	0.0	32.1	2.8	1.7	5.5
Before discharge	n	13	13	13	13	13	13	13	13
	Min.	0.6	0.2	0.0	0.0	0.0	1.6	0.0	4.6
	Max.	40.5	24.6	17.1	0.0	72.0	30.0	14.0	5.8
	Mean	8.98	4.75	5.36	0.0	18.6	9.83	2.38	5.3
	S.E.	3.18	1.96	1.67	0.0	7.30	2.25	1.00	0.099
At discharge	n	13	13	13	13	13	13	13	13
	Min.	0.6	0.1	0.0	0.0	0.5	1.8	0.0	4.5
	Max.	34.5	21.3	17.2	0.0	79.6	29.0	16.1	6.1
	Mean	8.38	4.22	4.99	0.0	17.9	10.11	3.07	5.3
	S.E.	2.80	1.73	1.78	0.0	7.59	2.35	1.19	0.133
After discharge	n	13	13	13	13	13	13	13	13
	Min.	0.0	0.1	0.0	0.0	0.0	0.0	0.0	4.6
	Max.	46.9	17.7	21.0	0.0	77.2	29.0	16.0	6.0
	Mean	9.20	3.88	5.30	0.0	17.2	10.81	2.42	5.4
	S.E.	3.80	1.76	2.02	0.0	7.29	2.59	1.16	0.126
ANOVA	MSE (24 d.f)	4.53	4.01	1.49	-	5.05	2.77	0.80	0.019
	F value	0.52	0.63	0.34	-	1.25	1.19	2.43	1.69
		ns	ns	ns	-	ns	ns	ns	ns

Notes:

n - number of sample means.

S.E. - standard error.

ns - not significant.

TABLE 3b. THIRTEEN-YEAR EFFECTS OF POME APPLICATION ON NUTRIENT CONTENTS AND pH VALUE OF GROUNDWATER AT THE MONITORING SITE, C.E.P. RENGAM ESTATE, KLUANG, JOHOR

Description of samples	Year	N (mg litre ⁻¹)	NO ₃ ⁻ (mg litre ⁻¹)	NH ₄ ⁺ (mg litre ⁻¹)	P (mg litre ⁻¹)	K (mg litre ⁻¹)	Ca (mg litre ⁻¹)	Mg (mg litre ⁻¹)	pH
Groundwater - treated area	1985	6.5	7.4	5.6	0.0	5.9	3.7	2.7	5.4
	1986	7.3	7.4	2.1	0.1	7.6	12.9	5.3	4.5
	1987	6.5	7.3	4.2	0.0	3.3	9.4	1.4	4.6
	1988	72.1	21.2	64.4	1.5	9.0	28.0	2.7	5.2
	1989	50.5	8.1	27.9	1.6	13.1	26.9	4.1	4.4
	1990	5.2	15.1	5.1	0.0	9.1	11.9	2.0	5.5
	1991	5.7	10.5	4.5	0.0	3.8	11.9	1.0	5.6
	1992	8.2	19.7	4.1	0.0	0.6	30.1	8.9	6.0
	1993	9.9	0.7	0.3	0.0	1.2	11.6	1.3	5.1
	1994	45.4	23.1	27.3	0.0	95.8	15.0	2.5	5.9
	1995	38.0	25.6	16.4	0.0	26.0	63.0	18.0	5.8
	1996	5.5	9.1	5.8	0.0	8.4	5.6	1.1	5.1
	1997	64.3	17.6	19.7	6.9	47.0	18.1	5.5	4.9
	Mean	25.0	13.3	14.4	0.8	17.8	19.1	4.3	5.2
Groundwater - untreated (adjacent area)	1997	5.54	9.44	5.86	0.00	8.77	5.38	1.03	5.1

concentration of Fe in the surface water however was slightly high, ranging from 0.32 – 0.37 mg litre⁻¹, but close to the acceptable limit of 0.30 mg litre⁻¹. It was also noticed that the Fe levels in samples taken before the discharge points were slightly higher than in samples at and after the discharge point.

The mean levels of heavy metals in the groundwater over the 13-year period are summarized in *Tables 4b* and *4c*. Generally, the levels of trace metals in the groundwater appeared relatively low. The results also showed that there was no significant difference between the samples taken from the POME applied area and from the adjacent area for almost all the heavy metals monitored. Most of the heavy metal concentrations in the groundwater complied with the DOE standards (*Table 6*), except for Fe (1.0 mg litre⁻¹). The mean concentration of Fe in the groundwater over the monitoring period was 1.79 mg litre⁻¹, which was quite marginal. Since palm oil contains a relatively low natural Fe content, it may therefore be concluded that the slightly high Fe level in the palm oil was due to contamination (Ab Gapor and Ong, 1982). The sources of contamination could also be due to absorption of Fe from the milling machinery or absorption from the storage tanks or even impurities. Ab Gapor and Ong (1982) also suggested that several practices could reduce the trace metal contents, including that of Fe, through implementing proper harvesting and handling of FFB and also by improving the milling technology, storage and handling work.

Additionally, most plants, including oil palm, take up some of the trace metals, like Mn, Fe, Cu, Zn and B, retained by the soil because they are essential micronutrients for the growth and development of plants. The results also showed very little to no accumulation of heavy metals in both the surface and groundwater from land application of digested-POME to an oil palm field.

CONCLUSION

Raw- and tank-digested POME contain relatively high contents of plant nutrients and relatively low contents of heavy metals except iron. Many workers through their respective trials have shown the fertilizer values of POME for oil palm and other crops.

The results from the monitoring work indicate that the application of digested-POME to the field at a controlled loading rate and frequency did not contaminate the water quality. There were no significant increases in pollutants in both the surface and groundwater. Based on this long term study, no heavy metal accumulation was detected in the water through repeated application of effluent. This showed that the soil is a natural filter with most of the excess nutrients being taken up by the palms.

ACKNOWLEDGEMENTS

The authors would like to thank the Director—General of MPOB for permission to

TABLE 3c. EFFECTS OF POMÉ APPLICATION ON NUTRIENT CONTENTS AND pH VALUE OF GROUNDWATER AT THE MONITORING SITE, C.E.P. RENGAM ESTATE, KLUANG, JOHOR (1997)

Description of samples	Sample No.	N (mg litre ⁻¹)	NO ₃ ⁻ (mg litre ⁻¹)	NH ₄ ⁺ (mg litre ⁻¹)	P (mg litre ⁻¹)	K (mg litre ⁻¹)	Ca (mg litre ⁻¹)	Mg (mg litre ⁻¹)	pH
Groundwater - treated area	1	34.72	10.20	14.00	17.65	87.00	26.00	10.00	4.8
	2	45.36	32.60	23.24	23.75	82.50	22.00	8.00	3.5
	3	37.52	12.90	28.00	9.00	50.00	12.50	5.50	4.6
	4	40.60	47.20	10.36	8.40	49.00	14.50	4.50	5.8
	5	67.48	29.80	24.92	10.00	59.00	14.50	6.50	6.2
	6	68.60	9.40	28.84	0.00	23.50	20.50	3.50	4.7
	7	90.72	5.20	14.56	0.00	25.00	19.00	3.50	4.4
	8	91.56	7.80	15.68	0.00	27.00	19.00	3.50	4.3
	9	80.08	14.60	10.92	0.00	25.50	16.00	6.00	6.5
	10	86.80	6.50	26.04	0.00	39.00	17.00	3.50	4.5
Groundwater - untreated (adjacent area)	1	5.60	28.43	8.68	0.00	19.00	2.04	1.06	2.9
	2	5.32	6.67	6.44	0.00	8.93	1.64	0.49	3.8
	3	5.60	7.12	5.88	0.00	9.39	2.60	0.75	4.2
	4	5.60	7.47	5.88	0.00	20.00	1.76	0.56	5.0
	5	6.16	20.69	7.00	0.00	10.00	3.30	1.20	4.2
	6	4.56	0.10	5.88	0.00	0.66	9.97	1.26	5.9
	7	5.88	13.42	5.32	0.00	11.69	4.99	1.89	5.5
	8	5.32	1.91	5.32	0.00	2.60	6.79	1.07	5.9
	9	5.32	1.97	4.20	0.00	8.00	6.59	0.95	5.2
	10	5.60	20.63	5.88	0.00	9.39	6.30	1.48	5.5
	11	5.32	0.30	5.60	0.00	0.46	10.94	1.27	6.4
	12	6.16	3.35	6.72	0.00	5.86	2.79	0.49	5.5
	13	5.60	10.65	3.36	0.00	8.00	10.22	0.98	5.7
Treated area	n	10	10	10	10	10	10	10	10
	Min.	34.72	5.20	10.36	0.00	23.50	12.50	3.50	3.5
	Max.	91.56	47.20	28.84	23.75	87.00	26.00	10.00	6.5
	Mean	64.34	17.62	19.66	6.88	46.75	18.10	5.45	4.9
	S.E.	7.26	4.44	2.29	2.70	7.44	1.28	0.71	0.29
Untreated (adjacent area)	n	13	13	13	13	13	13	13	13
	Min.	4.56	0.10	3.36	0.00	0.46	1.64	0.49	2.9
	Max.	6.16	28.40	8.68	0.00	20.00	10.90	1.89	6.4
	Mean	5.54	9.44	5.86	0.00	8.77	5.38	1.03	5.1
	S.E.	0.12	2.49	0.36	0.00	1.65	0.94	0.11	0.28
Paired t-test	Difference	58.8	8.2	13.8	6.9	38.0	12.7	4.4	-0.1
	T value with 21 d.f.	19.31	1.70	6.78	2.93	5.63	8.21	7.04	-0.3
		***	ns	***	**	***	***	***	ns

Notes:

n - number of samples.

S.E. - standard error.

ns - not significant.

** significant at the 1% level.

*** significant at the 0.1% level.

TABLE 4a. THIRTEEN-YEAR EFFECTS OF POME APPLICATION ON HEAVY METAL CONTENTS OF SURFACE WATER AT THE MONITORING SITE, C.E.P. RENGAM ESTATE, KLUANG, JOHOR

Description of samples	Year	Mn (mg litre ⁻¹)	Fe (mg litre ⁻¹)	Cu (mg litre ⁻¹)	Zn (mg litre ⁻¹)	Pb (mg litre ⁻¹)	B (mg litre ⁻¹)	Cd (mg litre ⁻¹)
Stream water - before discharge point	1985	n.d	0.19	n.d	0.02	n.d	n.d	n.d
	1986	n.d	0.15	n.d	0.02	n.d	n.d	n.d
	1987	n.d	0.16	n.d	0.02	n.d	n.d	n.d
	1988	n.d	0.16	n.d	0.04	n.d	n.d	n.d
	1989	n.d	0.03	n.d	0.05	n.d	n.d	n.d
	1990	n.d	0.00	n.d	0.02	n.d	n.d	n.d
	1991	0.01	0.13	0.01	0.01	n.d	n.d	n.d
	1992	0.03	0.15	n.d	0.04	n.d	n.d	n.d
	1993	n.d	0.30	n.d	0.03	n.d	n.d	n.d
	1994	0.01	0.53	n.d	0.03	n.d	n.d	n.d
	1995	n.d	2.30	n.d	n.d	n.d	n.d	n.d
	1996	n.d	0.06	n.d	n.d	n.d	n.d	n.d
	1997	n.d	0.60	n.d	n.d	n.d	n.d	n.d
Stream water - at discharge point	1985	n.d	0.22	n.d	0.03	n.d	n.d	n.d
	1986	n.d	0.10	n.d	0.01	n.d	n.d	n.d
	1987	0.02	0.21	n.d	0.03	n.d	n.d	n.d
	1988	n.d	0.31	n.d	0.06	n.d	n.d	n.d
	1989	n.d	0.29	n.d	0.05	n.d	n.d	n.d
	1990	n.d	0.00	n.d	0.03	n.d	n.d	n.d
	1991	n.d	0.12	0.02	0.01	n.d	n.d	n.d
	1992	0.01	0.12	n.d	0.04	n.d	n.d	n.d
	1993	n.d	0.30	n.d	0.02	n.d	n.d	n.d
	1994	0.01	0.22	n.d	0.03	n.d	n.d	n.d
	1995	n.d	1.20	n.d	n.d	n.d	n.d	n.d
	1996	n.d	0.50	n.d	n.d	n.d	n.d	n.d
	1997	n.d	0.50	n.d	n.d	n.d	n.d	n.d
Stream water - after discharge point	1985	n.d	0.00	n.d	n.d	n.d	n.d	n.d
	1986	n.d	0.01	n.d	0.07	n.d	n.d	n.d
	1987	n.d	0.14	n.d	0.05	n.d	n.d	n.d
	1988	n.d	0.19	n.d	0.04	n.d	n.d	n.d
	1989	n.d	0.08	n.d	0.06	n.d	n.d	n.d
	1990	n.d	0.00	n.d	0.03	n.d	n.d	n.d
	1991	0.02	0.12	n.d	0.00	n.d	n.d	n.d
	1992	0.01	0.11	n.d	0.06	n.d	n.d	n.d
	1993	0.00	0.30	n.d	0.13	n.d	n.d	n.d
	1994	0.01	0.59	n.d	0.02	n.d	n.d	n.d
	1995	n.d	1.00	n.d	n.d	n.d	n.d	n.d
	1996	n.d	0.90	n.d	n.d	n.d	n.d	n.d
	1997	n.d	0.90	n.d	n.d	n.d	n.d	n.d
Before discharge point	n	13	13	13	13	13	13	13
	Min.	n.d	0.000	n.d	n.d	n.d	n.d	n.d
	Max	0.030	2.300	0.01	0.050	n.d	n.d	n.d
	Mean	0.004	0.366	0.00	0.022	n.d	n.d	n.d
	S.E.	0.0024	0.169	0.00	0.0045	-	-	-
At discharge point	n	13	13	13	13	13	13	13
	Min.	n.d	0.000	n.d	n.d	n.d	n.d	n.d
	Max.	0.020	1.200	0.02	0.060	n.d	n.d	n.d
	Mean	0.003	0.315	0.00	0.024	n.d	n.d	n.d
	S.E.	0.0018	0.084	0.00	0.0054	-	-	-
After discharge point	n	13	13	13	13	13	13	13
	Min.	n.d	0.00	n.d	n.d	n.d	n.d	n.d
	Max.	0.020	1.00	n.d	0.130	n.d	n.d	n.d
	Mean	0.003	0.334	n.d	0.035	n.d	n.d	n.d
	S.E.	0.0018	0.104	-	0.0108	-	-	-
ANOVA	MSE (24 d.f)	0.00003	0.656	-	0.00041	-	-	-
	F value	0.08	0.13	-	1.76	-	-	-
		ns	ns	-	ns	-	-	-

Notes:

n - number of sample means.
S.E. - standard error.
ns - not significant.
n.d - non-detectable.

**TABLE 4b. THIRTEEN-YEAR EFFECTS OF POME APPLICATION
ON HEAVY METAL CONTENTS OF GROUNDWATER AT THE MONITORING
SITE, C.E.P. RENGAM ESTATE, KLUANG, JOHOR**

Description of samples	Year	Mn (mg litre ⁻¹)	Fe (mg litre ⁻¹)	Cu (mg litre ⁻¹)	Zn (mg litre ⁻¹)	Pb (mg litre ⁻¹)	B (mg litre ⁻¹)	Cd (mg litre ⁻¹)
Groundwater - treated area	1985	n.d	5.32	n.d	0.16	n.d	n.d	n.d
	1986	0.03	4.43	0.060	0.70	n.d	n.d	n.d
	1987	n.d	2.06	n.d	0.06	n.d	n.d	n.d
	1988	n.d	2.80	n.d	0.10	n.d	0.01	n.d
	1989	n.d	1.89	n.d	0.19	n.d	0.01	n.d
	1990	n.d	0.14	n.d	0.05	n.d	n.d	n.d
	1991	0.025	1.27	0.023	0.03	n.d	n.d	n.d
	1992	0.063	0.46	0.005	0.06	n.d	n.d	n.d
	1993	0.028	0.18	n.d	n.d	0.008	n.d	n.d
	1994	0.017	1.44	n.d	0.04	n.d	n.d	n.d
	1995	n.d	1.43	n.d	n.d	n.d	0.03	n.d
	1996	n.d	0.83	n.d	n.d	n.d	n.d	n.d
	1997	n.d	0.69	n.d	n.d	n.d	n.d	n.d
	Mean		0.018	1.71	0.007	0.105	0.0006	0.003
Groundwater - untreated (adjacent area)	1997	n.d	0.71	n.d	n.d	n.d	n.d	n.d

Note:

n.d - non-detectable.

**TABLE 4c. EFFECTS OF POME APPLICATION ON HEAVY METAL CONTENTS
OF GROUNDWATER AT THE MONITORING SITE, C.E.P.
RENGAM ESTATE, KLUANG, JOHOR (1997)**

Description of samples	Sample No.	Mn (mg litre ⁻¹)	Fe (mg litre ⁻¹)	Cu (mg litre ⁻¹)	Zn (mg litre ⁻¹)	Pb (mg litre ⁻¹)	B (mg litre ⁻¹)	Cd (mg litre ⁻¹)
Groundwater - treated	1	n.d	1.00	n.d	n.d	n.d	n.d	n.d
	2	n.d	0.50	n.d	n.d	n.d	n.d	n.d
	3	n.d	0.00	n.d	n.d	n.d	n.d	n.d
	4	n.d	0.00	n.d	n.d	n.d	n.d	n.d
	5	n.d	2.50	n.d	n.d	n.d	n.d	n.d
	6	n.d	2.50	n.d	n.d	n.d	n.d	n.d
	7	n.d	1.00	n.d	n.d	n.d	n.d	n.d
	8	n.d	0.00	n.d	n.d	n.d	n.d	n.d
	9	n.d	1.50	n.d	n.d	n.d	n.d	n.d
	10	n.d	2.00	n.d	n.d	n.d	n.d	n.d
Groundwater - untreated (adjacent area)	1	n.d	0.10	n.d	n.d	n.d	n.d	n.d
	2	n.d	2.34	n.d	n.d	n.d	n.d	n.d
	3	n.d	0.84	n.d	n.d	n.d	n.d	n.d
	4	n.d	1.50	n.d	n.d	n.d	n.d	n.d
	5	n.d	0.01	n.d	n.d	n.d	n.d	n.d
	6	n.d	0.09	n.d	n.d	n.d	n.d	n.d
	7	n.d	2.33	n.d	n.d	n.d	n.d	n.d
	8	n.d	0.03	n.d	n.d	n.d	n.d	n.d
	9	n.d	0.04	n.d	n.d	n.d	n.d	n.d
	10	n.d	0.18	n.d	n.d	n.d	n.d	n.d
	11	n.d	0.06	n.d	n.d	n.d	n.d	n.d
	12	n.d	1.48	n.d	n.d	n.d	n.d	n.d
	13	n.d	0.22	n.d	n.d	n.d	n.d	n.d
Treated area	n	10	10	10	10	10	10	10
	Min.	n.d	0.00	n.d	n.d	n.d	n.d	n.d
	Max.	n.d	2.50	n.d	n.d	n.d	n.d	n.d
	Mean	n.d	1.10	n.d	n.d	n.d	n.d	n.d
	S.E.	-	0.31	-	-	-	-	-
Untreated (adjacent area)	n	13	13	13	13	13	13	13
	Min.	n.d	0.01	n.d	n.d	n.d	n.d	n.d
	Max.	n.d	2.34	n.d	n.d	n.d	n.d	n.d
	Mean	n.d	0.71	n.d	n.d	n.d	n.d	n.d
	S.E.	-	0.25	-	-	-	-	-
Paired t-test	Difference	-	0.29	-	-	-	-	-
	T value with 21 d.f	-	0.99	-	-	-	-	-
		-	ns	-	-	-	-	-

Notes:

- n - number of samples.
S.E. - standard error.
ns - not significant.
n.d - non-detectable.

TABLE 5. QUALITY OF POME AND SURFACE WATER OVER 13 YEARS APPLICATION, C.E.P. RENGAM ESTATE, KLUANG, JOHOR (1985 -1997)

Parameter	Source					DOE*
	Raw-POME	Digested-POME	Stream water before discharge point	Stream water at discharge point	Stream water after discharge point	
pH	4.7	7.3	5.3	5.3	5.4	6 - 9
K (mg litre ⁻¹)	1 809	2 072	18.6	17.9	17.2	-
NO ₃ (mg litre ⁻¹)	252	103	4.75	4.22	3.88	7.0
P (mg litre ⁻¹)	40	29	0.0	0.0	0.0	0.20
Cd (mg litre ⁻¹)	0.0	0.0	0.0	0.0	0.0	0.01
Cu (mg litre ⁻¹)	0.47	0.36	0.0	0.0	n.d	1.0
Fe (mg litre ⁻¹)	61.57	24.63	0.366	0.315	0.334	0.30
Pb (mg litre ⁻¹)	0.05	0.05	n.d	n.d	n.d	0.05
Mn (mg litre ⁻¹)	1.82	0.98	0.004	0.003	0.003	0.10

Notes:

* interim water quality standards of Malaysia,
Department of Environment, Malaysia.

n.d - non-detectable.

TABLE 6. QUALITY OF GROUNDWATER AT C.E.P. RENGAM ESTATE, KLUANG, JOHOR AFTER 13 YEARS OF POME APPLICATION (1985 - 1997)

Parameter	Source		DOE*
	Treated area	Untreated area (adjacent area)	
NO ₃ (mg litre ⁻¹)	13.3	9.4	10.0
Cd (µg litre ⁻¹)	0.0	0.0	5.0
Cu (µg litre ⁻¹)	7.0	n.d	1 000
Fe (mg litre ⁻¹)	1.7	0.7	1.0
Pb (µg litre ⁻¹)	0.6	n.d	100
Mn (µg litre ⁻¹)	18	n.d	200

Notes:

* interim groundwater quality standards of Malaysia,
Department of Environment, Malaysia.

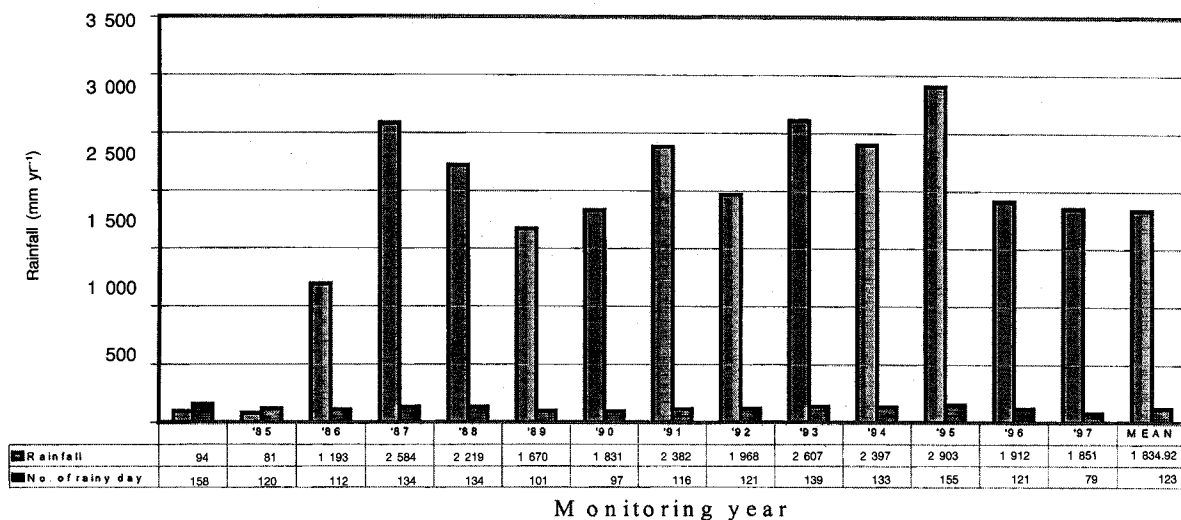
n.d - non-detectable.

publish this paper. Assistance given by Sime Darby Plantation and the Manager of C.E.P Rengam Estate is gratefully acknowledged.

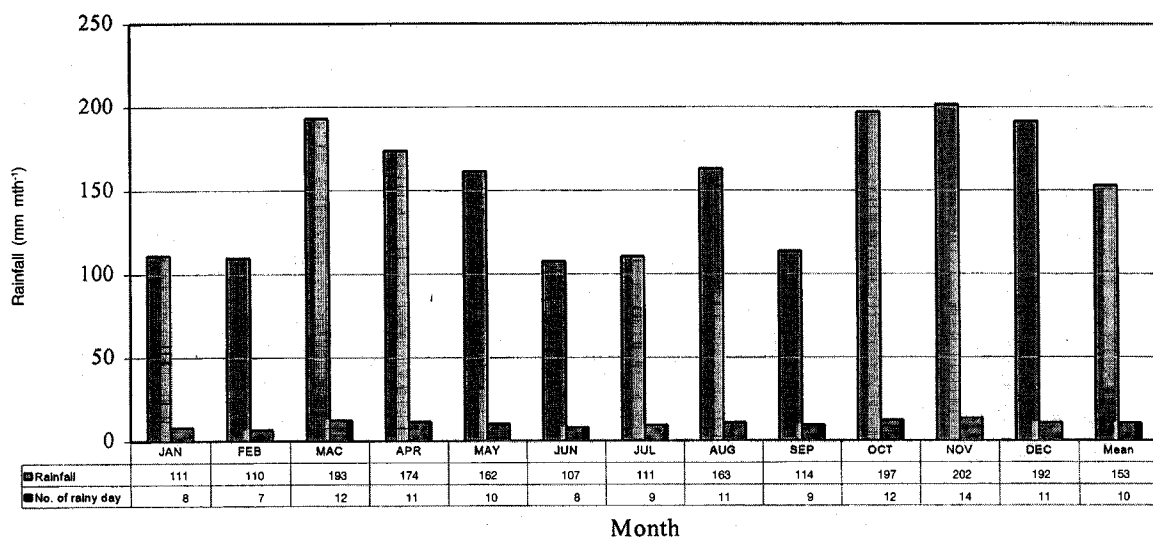
REFERENCES

- AB GAPOR, M T and AUGUSTINE ONG, S H (1982). Some aspects of trace metals in palm oil. *PORIM Bulletin No. 4*: 19-26.
- ALEXANDER, M (1977). The nitrogen cycle. *Introduction to Soil Microbiology*. Wiley, New York. p. 225-30.
- KHALID, H and ZIN, Z Z (1994). Land application of palm oil mill effluent (POME) on oil palm using a tractor-tanker and flatbed system. *PORIM Bulletin No. 28*: 20-29.
- LIM, C H; P'NG, T C; CHAN, K W and CHOOI, S Y (1983). Land application of digested palm oil mill effluent (POME) by sprinkler system. *Proceedings of the Seminar on Land Application of Palm Oil and Rubber Factory Effluents* (Lim, K H; Bachik, A T and Poon, Y C eds.). Malaysian Society of Soil Science. p. 72-89.
- LIM, C H (1987). Trials on long-term effects of application of POME on soil properties, oil palm nutrition and yields. *Proceedings of the 1987 International Oil Palm/Palm Oil Conferences - Progress and Prospects* (Abdul Halim, H; Chew, P S; Wood, B J and Pushparajah, E eds.). Incorporated Society of Planters. p. 575-595.
- LIM, C H; P'NG, T C and CHAN, K W (1991). Nutrient recycling through utilization of palm oil mill effluent. *Proceedings of the 1991 PORIM International Palm Oil Conference - Progress, Prospects Challenges Towards the 21st Century* (Yusof, B; Jalani, B S; Chang, K C; Cheah, S C; Henson, I E; Norman, K; Paranjothy, K; Rajanaidu, N; Mohd Tayeb, D and Ariffin, D eds.). PORIM. p. 261-269.
- MOHD HASHIM, T (1991). Treated POME as nutrient source for oil palm. *Proceedings of the 1991 PORIM International Palm Oil Conference - Progress, Prospects and Challenges Towards the 21st Century* (Yusof, B; Jalani, B S; Chang, K C; Cheah, S C; Henson, I E; Norman, K; Paranjothy, K; Rajanaidu, N; Mohd Tayeb, D and Ariffin, D eds.). PORIM. p. 244-260.
- MOHD TAYEB, D; LIM, K H; ZIN, Z Z and ABDUL HALIM, H (1987). Recent studies on the effects of land application of palm oil mill effluent on oil palm and the environment. *Proceedings of the 1987 International Oil Palm/Palm Oil Conferences - Progress and Prospects* (Abdul Halim, H; Chew, P S; Wood, B J and Pushparajah, E eds.). PORIM and Incorporated Society of Planters. p. 596-604.
- PALANIAPPAN, S; SYED SOFI, S O and PALANIAPPAN, V M (1983). Land application of raw palm oil mill effluent (POME): studies on leaching and, decomposition and nutrient release of the residues. *Proceedings of the Seminar on Land Application of Palm Oil and Rubber Factory Effluents* (Lim, K H; Bachik, A T and Poon, Y C eds.). Malaysian Society of Soil Science. p. 180-217.
- TAN, K S (1983). Land application of digested palm oil mill effluent to mature oil palm on inland soils - some preliminary results. *Proceedings of the Seminar on Land Application of Palm Oil and Rubber Factory Effluents* (Lim, K H; Bachik, A T and Poon, Y C eds.). Malaysian Society of Soil Science. p. 117-133.
- YAWALKAR, K S; AGARWAL, J P and BOKDE, S (1977). *Manure and Fertilizers*. Agri-Hort. Pub. House. 379 pp.
- YEOW, K H and GURMIT, S (1983). Land application of plantation effluent. *MOPGC Internal Report*.
- ZIN, Z Z; MOHD TAYEB, D; MA, A N; YEOW, K H and LIM, K H (1983). Monitoring and environmental assessment - water quality. *Proceedings of the Seminar on Land Application of Palm Oil and Rubber Factory Effluents* (Lim, K H; Bachik, A T and Poon, Y C eds.). Malaysian Society of Soil Science. p. 163-179.
- ZIN, Z Z; HAMDAN, A B and KHALID, H (1995). Land application of palm oil mill effluents guidelines and effects on soil, water and crop. *Proceedings of Workshop on Environmental Quality Management in the Plantations* (Jalani, B S; Chan, K W and Gurmit, S eds.). PORIM and Malaysian Oil Palm Growers' Council. p. 46-54.

Rainfall distribution, C.E.P Rengam Estate,
Kluang, Johor (1984-1997)



Monthly rainfall distribution, C.E.P Rengam Estate,
Kluang, Johor (1984 - 1997)



INTERIM WATER QUALITY STANDARDS OF MALAYSIA

Classes							
Parameter	Unit	I	IIA	IIB	III	IV	V
Temperature	° C	normal	-	normal	-	-	-
pH	-	6.5-8.5	6 - 9	6 - 9	6 - 9	5 - 9	-
Conductivity	µS/cm	1 000	1000	-	-	6 000	-
Colour	Pt-Co	15	150	150	-	-	-
DO	mg litre ⁻¹	7	5-7	5-7	3-5	<3	<1
BOD	mg litre ⁻¹	1	3	3	6	12	>12
COD	mg litre ⁻¹	10	25	25	50	100	>100
Ammoniacal-N	mg litre ⁻¹	0.1	0.3	0.3	0.9	2.7	>2.7
Salinity	10 ⁻³	0.5	1	-	-	2	-
K	mg litre ⁻¹	Natural	-	-	-	-	-
F	mg litre ⁻¹	Natural	1.5	1.5	10	1	>1
NO ₃	mg litre ⁻¹	Natural	7	7	-	5	>5
P	mg litre ⁻¹	Natural	0.2	0.2	0.1	-	-
S	mg litre ⁻¹	Natural	0.05	0.05	0.001	-	-
Cd	mg litre ⁻¹	Natural	0.01	0.01	0.01	0.01	>0.01
Cu	mg litre ⁻¹	Natural	1	1	-	0.2	>0.2
Fe	mg litre ⁻¹	Natural	0.3	0.3	1	1.5	>5
Pb	mg litre ⁻¹	Natural	0.05	0.05	0.02	5	>5
Mn	mg litre ⁻¹	Natural	0.1	0.1	0.1	0.2	>0.2
Ni	mg litre ⁻¹	Natural	0.05	0.05	0.9	0.2	-

Source: Department of Environment, Malaysia.

Class I: represents water bodies of excellent quality. Standards are set for the conservation of natural environment in its undisturbed state. Water bodies such as those in the national park areas, fountainheads, and a high land and undisturbed areas come under this category where strictly no discharge of any kind is permitted. Water bodies in this category meets the most stringent requirements for human health and aquatic life protection.

Class II: represents water bodies of good quality. Most existing raw water supply sources come under this category. In practice, no body contact activity is allowed in the water prevention of probable human pathogens. There is a need to introduce another for water bodies not used for water supply but of similar quality, which may as class IIB. The determination of class IIB standards is based on criteria for recreational use and protection of sensitive aquatic species.

Class III: is defined with the primary objective of protecting common and moderately tolerant aquatic species of economic value. Water under this qualification may be used for water supply with extensive/advanced treatment. This class is also defined to suit livestock drinking needs.

Class IV: defines water quality required for major agricultural irrigation activities which may not cover minor applications to sensitive crops.

Class V: represents other waters that do not meet any of the above uses.

Appendix 3

GROUNDWATER QUALITY IN MALAYSIA (Evaluation Bench Marks)

Chemical	Bench mark	Chemical	Bench mark
Sulphate	400 mg litre ⁻¹	Chloride	250 mg litre ⁻¹
Nitrate	10 mg litre ⁻¹	Phenolics	0.002 mg litre ⁻¹
Manganese	200 µg litre ⁻¹	Iron	1.0 mg litre ⁻¹
Chromium	50 µg litre ⁻¹	Copper	1 000 µg litre ⁻¹
Zinc	1 500 µg litre ⁻¹	Lead	100 µg litre ⁻¹
Arsenic	50 µg litre ⁻¹	Cadmium	5.0 µg litre ⁻¹
Selenium	10 µg litre ⁻¹	Mercury	1.0 µg litre ⁻¹

Source: Montgomery Watson.