Properties of Boiler Fly Ash from Various Palm Oil Mills

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ABSTRAK

Ciri-ciri fizik dan kerencaman kimia bagi abu terbang dari beberapa dandang kilang sawit dilaporkan di dalam kertas kerja ini. Sebanyak sepuluh sampel telah diambil untuk penganalisaan. Kajian terhadap taburan saiz zarah telah dibuat melalui analisis ayak. Keputusan menunjukkan saiz zarah adalah dalam lingkungan kurang dari 20µm hingga melebihi 2000µm. Kandungan unsur-unsur zat makanan dan logam telah dikaji menggunakan alat spektrofotometer penyerapan atom. Ini termasuk unsur-unsur N, P, K, Mg, Ca, Cu, Zn and Fe. Analisa mendapati kesemua sampel abu terbang mengandungi unsur-unsur tersebut. Kandungan unsur Fe didapati agak tinggi di dalam semua sampel abu terbang.

INTRODUCTION

Palm oil milling processes consist of sterilization of fresh fruit bunches (FFB), stripping, pressing, clarification and purification of the crude oil, nut cracking, and kernel recovery. Generally, palm oil mills generate their own steam and electricity. Pressed fibre and shell, the waste products from the mill, are used as fuels for the boilers. The combustion produces boiler fly ash and clinker. About 4kg to 6kg of fly ash are produced for every tonne of FFB processed. At present, this fly ash is considered solid waste and is disposed off on the land.

Fly ash can be used as an adsorbent for heavy metals (Weng and Huang, 1994; Hashim *et al.*, 1996) and for polishing palm oil mill effluent (Rusnani *et al.*, 1997). Fly ash from other sources is used in cement and concrete products, structural fills, road construction and coal mining applications (Golden, 1987).

Fly ash is freely available at the mill and its utilization would help remove the waste produced. This paper presents general information on the physical and chemical properties of boiler fly ash from 10 palm oil mills. The properties include particle size distribution, moisture content, apparent density and loss on ignition. This paper also covers nutrient elements and metal concentrations in the fly ash.

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MATERIALS AND METHOD

Fly ash samples were obtained from 10 palm oil mills. The samples were collected twice from each mill. The boiler specifications for the mills are illustrated in *Table 1.* All analyses were done on the fly ash as produced.

The samples were first dried in an oven at 105°C for 24 hours prior to particle size analysis. The particle size distribution was determined by the fractions of the sample retained on each of a series of successively finer sieve shakers. The moisture contents of the samples were calculated from their weights after heating at 135°C for two hours. The apparent density was determined by pre-drying the sample to constant weight at 105°C and the volume measured by adding the test material to a 100ml graduated cylinder at a uniform rate using a vibrating feeder to obtain maximum packing. Weight loss on ignition of the fly ash samples was determined by incinerating the ash at 1100°C for two hours to remove the moisture from the samples.

Nutrient elements and metal contents were determined by an atomic absorption spectrophotometer. These include N, P, K, Mg, Ca, Cu, Zn and Fe.

RESULTS AND DISCUSSION

Fly ash from a palm oil mill boiler is greyish to

TABLE 1. BOILER SPECIFICATIONS

Mill	Specifications						
	Model	**Type**	**Year built**	**Rated capacity (lbs/hr)**	**Operating pressure (psig)**	**Dust collector**	**Super heater**
1	Towler	Water-tube	1989	35 000	300	Multi-cyclone	Yes
2	Vicker Hoskin	Fire- tube	1980	15 000	250	Nil	Nil
3	Babcock Wilson	Water-tube	1972	20 000	300	Multi-cyclone	Yes
4	Babcock Wilson	Water-tube	1972	25 000	300	Multi-cyclone	Yes
5	Vicker Hoskin	Fire-tube	1975	15 000	250	Nil	Nil
6	Dahyong	Water-tube	1981	30 000	300	Multi-cyclone	Yes
7	Takuma	Water-tube	1979	30 000	300	Multi-cyclone	Yes
8	Takuma	Water-tube	1983	40 000	300	Multi-cyclone	Yes
9	Takuma	Water-tube	1983	40 000	300	Multi-cyclone	Yes
10	Fraser	Water-tube	1978	40 000	300	Multi-cyclone	Nil

black in colour. It contains mainly unburnt carbon as shown in *Figure 1*. The structures of the fly ash are grainy and flaky type. Some shell particles are also found in the ash. These types of structures are expected as palm oil mills use fibre and shell as boiler fuel. *Table 2* shows the particle size distribution of boiler fly ash from various palm oil mills. The sizes range from less than 20μm to more than 2000μm. Nine mills produce 48% to 67% of fly ash with particle sizes ranging from 60μm to 70μm. Mill 2 produces fly ash with the largest particles, 28% of them falling between 2000μm - 3000μm. The variation in particle sizes from different mills are probably due to the different ratios of fibre and shell used as well as boiler operation. Mill 2, for example, used more shell for fuel. Burning shell tends to produce larger particles in fly ash. Particle size distribution is one of the properties for determining the usefulness of the ash as a substitute for a portion of the cement in concrete and in soil-stabilization mixtures (Gutierrez, *et al.*, 1993).

The results on moisture content and apparent density are presented in *Table 3*. Seven mills produced fly ash with moisture contents of less than 5%, whereas fly ash from Mills 2, 4, and 6 had moisture contents of 26.38%, 23.82% and 21.21%, respectively. These three mills sprayed water on their ash to prevent them from being blown about. There were no particles below 20μm from these mills.

Apparent density is one of the quality control parameters commonly used in the manufacture of active carbons. The apparent densities of the fly ash from various mills are given in *Table 3*. All the samples had low apparent densities ranging from 0.2 to 0.6g/ml.

Loss on ignition is a measure of the unburnt carbon remaining. Seven mills produced fly ash with high combustible carbon contents of 53.4% to 93.7% (*Table 3*). Ash from Mill 7 had the highest loss on ignition which indicated that it contained predominantly unburnt carbon. Mills 2,

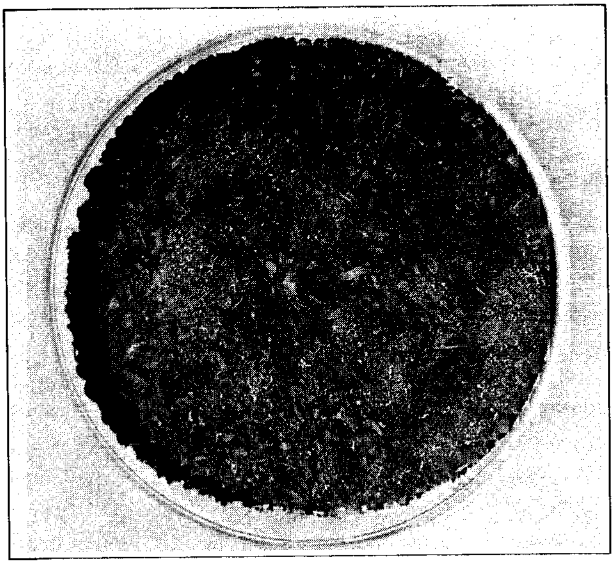

Figure 1. Photograph of raw palm oil boiler fly ash.

TABLE 2. PARTICLE SIZE DISTRIBUTION OF FLY ASH FROM VARIOUS PALM OIL MILLS

Particle size (μm)	Particle distribution (%)									
	Mill 1	Mill 2	Mill 3	Mill 4	Mill 5	Mill 6	Mill 7	Mill 8	Mill 9	Mill 10
- 20	1.58	-	0.19	-	4.22	-	0.18	0.58	0.10	0.08
20 - 40	10.51	3.23	1.00	7.20	13.81	1.48	0.53	7.25	6.56	1.41
40 - 60	10.42	3.01	0.89	13.46	10.43	3.12	0.72	10.58	9.35	2.09
60 - 70	63.23	19.61	51.02	48.47	67.12	48.58	50.42	62.47	65.42	55.23
70 - 320	9.19	9.15	18.13	11.89	3.20	18.58	20.94	11.20	13.86	17.60
320 - 560	4.44	18.48	18.08	16.12	0.60	23.01	23.50	7.53	4.30	20.12
560 - 2000	0.62	18.63	8.69	2.74	0.43	5.00	3.37	0.73	0.37	3.34
2000 - 3000	-	27.87	2.00	0.12	0.19	0.51	0.49	0.02	0.04	0.20

TABLE 3. PROPERTIES OF FLY ASH

Mill	Weight loss on ignition (%)	Moisture content (%)	Apparent density (g/ml)
1	86.13	3.06	0.647
2	31.00	26.38	0.486
3	37.63	1.50	0.219
4	37.72	23.82	0.383
5	91.28	0.89	0.539
6	56.58	21.21	0.564
7	93.71	1.88	0.284
8	78.52	1.13	0.425
9	60.78	1.74	0.301
10	53.42	4.64	0.486

3 and 4 produced fly ash with combustible carbon contents of 31.0%, 37.6% and 37.7%, respectively.

Table 4 presents the contents of the nutrient elements (N, P, K, Mg and Ca) in the fly ash. P, K, Mg and Ca were present in all the samples. There were 0.28% - 1.33% P, 1.02% - 4.31% K, 0.29% - 2.60%Mg and 0.39% - 3.24%Ca. Trace amounts of N were also present. The K content was particularly high. Therefore, rather than throwing it away, fly ash can be used as fertilizer.

The metal contents in the fly ash are given in *Table 5*. The metal content is important when fly ash is used as a substitute for a portion of the cement in concrete (Gutierres *et al.*, 1993). Fe was the major constituent in all the samples with concentrations ranging from 630ppm to 7180ppm. The highest concentration came from Mill 8. The concentrations of Cu and Zn ranged from 21ppm to 134ppm and 11ppm to 210ppm, respectively. Fly ash from Mill 2 that had the largest particles generally contained lower concentrations of Cu, Zn and Fe than the others. Ash from Mill 5 had highest concentration of Zn (210ppm). Other mills produced ash with less than 40ppm Zn. Mill 5 also produced ash with the second highest concentrations of Fe and Cu at 5645ppm and 110ppm, respectively. The extraction of crude palm oil from FFB involves physical processes in which wear and tear of the machinery occur during operation. This may have caused high Fe contents in fibre and shell. However, as the mill machinery does not contain Cu or Zn, these metals would have originated from the fruits or the soil (Zulkifli, 1998).

CONCLUSION

The benefit of using the fly ash to polish palm oil mill effluents has been accepted. The physical and chemical properties of palm oil mills boiler fly ash presented here in this article expand the potential use of the properties of fly ash as fertilizer supplements. The particle sizes vary from less than 20μm to more than 2000μm. Majority of the particles fall between 60μm and 70μm. Seven mills produce

TABLE 4. NUTRIENT ELEMENTS IN BOILER FLY ASH

Mill	Nutrient elements % on dry weight				
	N	P	K	Mg	Ca
1	0.27	1.01	2.84	1.26	2.74
2	0.67	0.28	1.02	0.36	0.39
3	0.49	0.29	1.14	0.32	0.52
4	0.65	0.69	1.72	0.47	0.64
5	0.40	1.33	4.31	2.60	2.29
6	0.52	0.39	1.75	0.29	0.47
7	0.61	0.67	1.45	0.58	1.12
8	0.29	1.03	2.99	1.38	3.24
9	0.21	0.89	2.71	1.08	2.32
10	0.69	0.47	1.51	0.54	0.62

TABLE 5. METAL CONCENTRATIONS OF FLY ASH (ppm)

Mill	Cu	Zn	Fe
1	68.0	38.0	5 100
2	22.0	17.0	630
3	21.0	11.0	2 130
4	47.0	21.5	1 645
5	110.0	210.0	5 645
6	48.0	14.5	2 425
7	134.0	31.5	2 600
8	103.0	33.5	7 180
9	48.5	22.5	5 290
10	40.5	21.0	2 735

ashes with moisture content less than 5%. All samples had low apparent density. Plant nutrients- N, P, K, Mg and Ca were found in the fly ash samples. Metals such as Cu, Zn and Fe were also detected with the concentration of Fe very high in all the samples.

ACKNOWLEDGEMENT

Thanks are due to Hisham Esa for his assistance in carrying out the analyses. The authors are also grateful to the Director-General of PORIM for his permission to publish this paper.

REFERENCES

GOLDEN, D M (1987). EPRI coal ash utilization research. *Energy, 11*: 1377 - 1387.

GUTIERREZ, B; PAZOS, C and COCA, J (1993). *Characterization and Leaching of Coal Fly Ash. Vol. II,* p. 279-286.

HASHIM, M A; CHU, K H; CHITGUPPA, R and MA, A N (1996). Adsorption of copper by fly ash obtained from oil-palm waste. Presented at the 6th. JSPS-VCC Seminar, Kyoto University, Kyoto, Japan.

RUSNANI, A M; MA, A N and NOOR AIDAR, H (1997). A preliminary study on the treatment of effluent discharge from a palm oil mill using boiler fly ash. *Proc. of the National Seminar on Palm Oil Milling, Refining Technology and Quality,* Kota Kinabalu, Sabah, p. 178 - 183.

WENG, C H and HUANG, C P (1994). Treatment of metal industrial waste water by fly ash and cement fixation. *Journal of Environmental Engineering, Vol. 120, No. 6* :1470-1487.

ZULKIFLI, H (1998). Personal communication, Palm Oil Research Institute of Malaysia, Bangi, November, 1998.