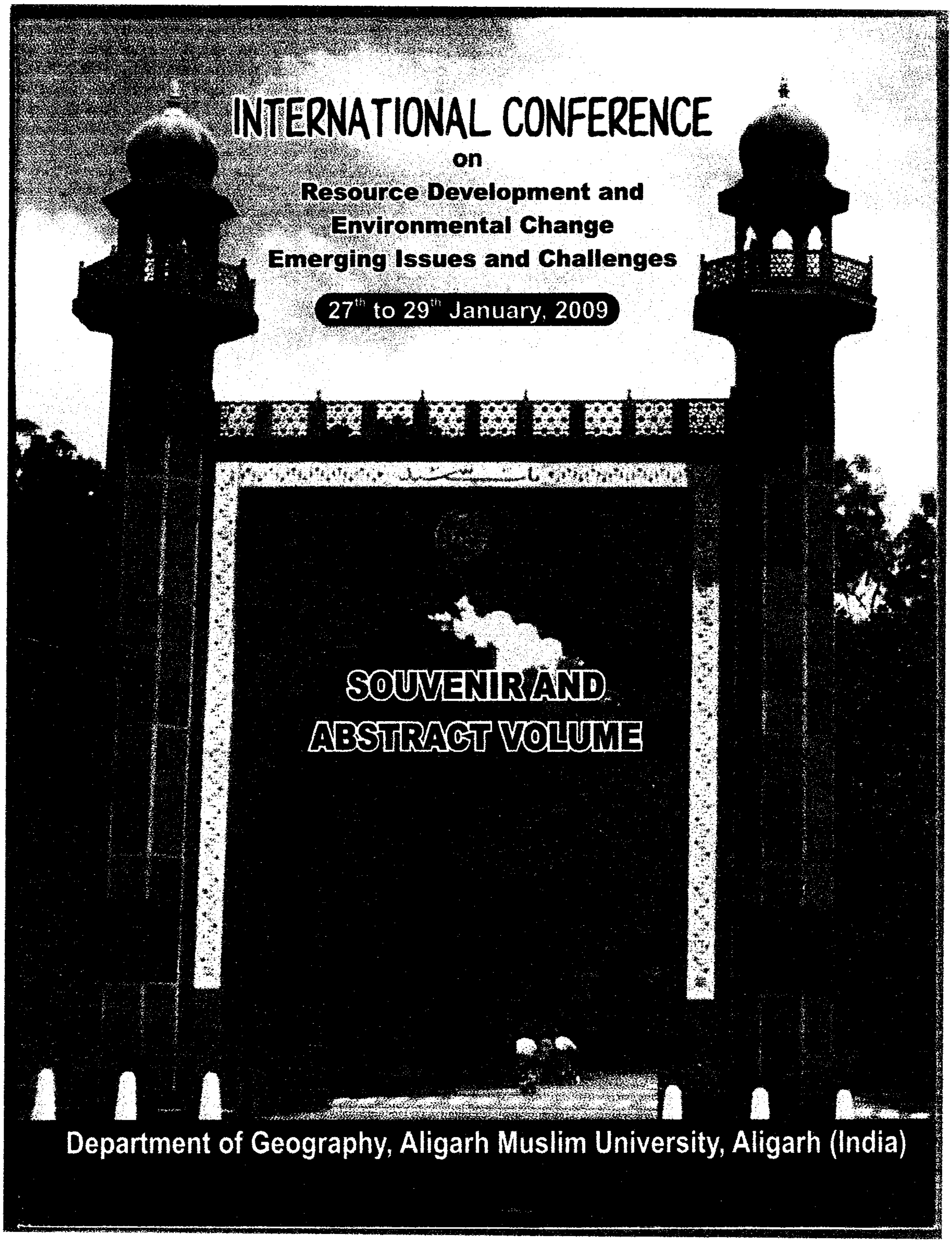
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Statistical Analysis of Solid Waste Generated in Selected Palm Oil Mill in Malaysia

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Abstract:
Similar types of industry sometimes have different solid waste management. In this study, Discriminant Analysis (DA) and Principal Components Analysis (PCA) were applied to analyze the solid waste generation from the perspective of the amount of solid wastes generated such as empty fruit bunches (EFB), potash ash, fibre, and shell from 5 different oil palm mills industry. DA identified two functions responsible for discriminating the mills based on the solid waste generated from the mills, and it showed that the differences between mills mainly due to potash ash, EFB, and shell, affording 98.3% correct assignation. PCA identified only one component responsible for explaining 98.89% of the total variance in the data representing the average of selected parameters. This study illustrates the usefulness of multivariate statistical techniques in analyzing a huge and complex data that can be employed to identify the major sources of pollution and hence narrow the pollution identification processes.

Keywords: Solid waste, Palm oil mill, Discriminant analysis, Principal components

1. Introduction

The palm oil industry is one of the major agro-industries in Malaysia and it has contributed the biggest income to the country for many years (Abdulmuin et al., 2000). With the increasing demand of world vegetable oil for instance jumping from 58.8

million tones in year 1991/1992 to 109.2 million tones in year 2005 and to 137.9 million tones in year 2006, Malaysia will be one of the major exporters of world vegetable oil in future (Chai et al., 2007). The palm oil industry is an important contributor to the country's GDP (Gross Domestic Product) .Despite obvious benefits of this industrial development; it also significantly contributes to environmental degradation.

The entire crude palm oil processes do not need any chemical as a processing aid. However, there are a number of environmental problems at the factories, such as high water consumption, generation of a large amount of wastewater with a high organic content, and the generation of large quantities of solid wastes, air pollution and generation of noise from machine and air pollution (Chavalparit et al., 2006).

Solid waste was among the impact confronted by the mill. Palm oil mills produce significant quantities of by-products in the form of solid waste, such as empty fruit bunches from the stripping process, fibres, shell, and ash. Only 23% of raw materials are products, the rests are wastes or by-products. Most of the by-products can be reused in the production process or in other industries. Fibres (13.5% of FFB) are used as fuel in boilers to generate steam and energy, required for the mill operation. Shell (5.5% of FFB) and empty fruit brunch (EFB) (23% of FFB) are sold for use in other industries (DOE, 1999). The problems of solid waste in factories are improper storage and handling of solid waste material and improper land application techniques or solid waste management. These wastes consequently cause bad smell and dust that affect the surrounding communities. The entire crude palm oil process does not need any chemical as processing aid. Therefore, all substances found in the products, byproducts, and residues were originated from the fresh fruit bunch. Current industrial wastes and recoverable materials are empty fruit bunches, fibers, shells and ash (Chavalparit et al., 2006).

Analyzing environmental data by using the multivariate methods has increased tremendously in recent years. These methods are useful where several dependant variables are measured on each sampling unit. Multivariate analysis of variance (MANOVA) can be used to test the significant differences, while discriminant function (DF) has been used to identify the relative contribution of all variables to the separation of the groups (Abbas et al., 2007). Principal component analysis (PCA) is a data reduction technique used in distinguishing the number of significant variants. PCA was applied to explain the observed variance in the data and to understand the interrelationship between different parameters (Abbas et al., 2008).
Using the statistical approach facilitates the identification of processes that generate impacts such as solid wastes generation. In addition, it is important to identify the relative contribution of the types of solid wastes in distinguishing the mills with better solid waste management.

The objective of this study was to determine whether there is a difference in the amount of solid waste generated from five different mills.

2. Materials and Methods

2.1. Description of Study Sites

The background of the five palm oil mills (Mill A-E) studied comprehending the land area (in acres), operating hours and the amount of product, i.e crude palm oil produced are as follows:

Mill	Acreage	Operating hours	Tones of crude palm oil
A	40	15	200
B	15	8	60

C	24	5	100
D	17	15	120
E	33	15	130

The processes that were assessed in all the above mills were based on the production cycle divided into several sectors:

1. Sector A: Preliminary process comprised of sterilization process and stripping and digestion process.
2. Sector B: Oil clarification and purification process comprised of screening, decantering and centrifuging processes.
3. Sector C: Nut and fibre separation process comprised of depericarpering, hydrocyclone and nut cracking processes.

The secondary data for amount of solid waste generated was obtained from the mill authorities through reviewed of relevant document and interview.

2.3. Statistical Analysis.

2.3.1. Discriminant Analysis

Discriminant analysis is a multivariate technique used for two purposes, the first purpose is description of group separation in which linear functions of the several variables (discriminant functions (DFs)) are used to describe or elucidate the differences between two or more groups and identifying the relative contribution of all variable to separation of the groups. Second aspect is prediction or allocation of observations to group in which linear or quadratic functions of the variable (classification functions (CFs)) are used to assign an observation to one of the groups (Alvin, 2002; Johnson and Wichern, 2002)

2.3.2. Principal Components

Principal component analysis (PCA) is designed to transform the original variables into new uncorrelated variables called components, which are linear combinations of the original variables. The PCA is a data reduction technique used in determining the number of variates to explain the observed variances in the data (Alvin, 2002; Bryan, 1991; Dean and Richard, 2002).

3. Results and Discussion

Fibre and shell were generated from the nut/fibre separation process. The amount of fibre generated was around 3240 tonnes monthly whilst the amount of shell was 1320 tonnes monthly. This results in the total amount of fibre and shell generated from the process to be around 190 tonnes daily for 15 hours of operation period. Fibre and shell are also by products of the extraction of crude palm oil. Therefore the generation of these wastes is inevitable. As empty fruit bunches, improperly stored fibre and shell will cause potential health effect to the worker. Although generation of fibre and shell are inevitable, the amount of fibre and shell generated were lesser than empty fruit bunch.

The average amount of empty fruit bunches generated from Sector A: Preliminary process involving digestion and stripping process was around 119 tonnes for 15 hours operation hours daily. The hazard is due to the empty bunches being used as fuel for boilers that create air emissions with dark smoke and high particulate content.

Sector B with oil clarification and purification processes generated no solid wastes

In Sector C where the fruits are separated from the bunches the average amount of fibre generated is around 69 tonnes daily.

Solid Waste from Selected Palm Oil Mill

Based on Table 1.0, the average amount of empty fruit bunches generated from the five selected mills were 5521 tonnes per month from mill A, 1632 tonnes per month from mill B, 2859 tonnes per month from mill C, 3423 tonnes per month from mill D and 3673 tonnes per month from mill E. Besides that, the average amount of fibre generated were 3240 tonnes per month in mill A, 958 tonnes per month in mill B, 1662 tonnes per month in mill C, 2009 tonnes per month in mill D and 2323 tonnes per month in mill D whilst the average amount of shell generated were 1320 tonnes per month from mill A, 390 tonnes per month from mill B, 679 tonnes per month from mill C, 819 tonnes per month from mill D and 895 tonnes per month from mill E. Empty fruit bunches contribute the highest amount of solid waste with 23% of fresh fruit bunches processed. Shell and fibre contribute 5.5% and 13.5% of fresh fruit bunches processed respectively whilst potash ash contribute lesser amount of solid waste with 0.5% of fresh fruit bunches processed (DOE, 1999). Therefore the amounts of solid wastes generated are merely dependent on the amount of fresh fruit bunches processed daily. Palm oil mill A processed the highest amount of fresh fruit bunches with the volume approximately 1000 tonnes daily. This is followed by mills E, D and C with the volume approximately 650 tonnes, 600 tonnes and 500 tonnes daily respectively. Palm oil mill B processed the least amount of fresh fruit bunches with the amount approximately 300 tonnes daily. Hence mill A has generated the highest amount of solid wastes and mill B the lowest amount. Besides that, the quantity of the wastes also depends on the quality of the fresh fruit bunches (Prasertsan and Prasertsan, 1996). According to the authors, high quality fresh fruit bunches will generate lesser wastes than low quality fresh fruit bunches. The amount of empty fruit bunches (EFB) generated from a low quality fresh fruit bunches are approximately 59% of the fresh fruit bunches whilst amount of fibre and shell generated are 13.9% and 10.6% respectively.

Table 1.0 Average amount of wastes in the form of empty fruit bunches, fibre and shell generated from the palm oil mills

Empty Fruit Bunches (tonnes)					
Months	*Palm oil mill A*	*Palm oil mill B*	*Palm oil mill C*	*Palm oil mill D*	*Palm oil mill E*
October 2007	5520	1656	2760	3312	3588
November 2007	5500	1601	3036	3257	3698
December 2007	5432	1573	2926	3395	3665
January 2008	5765	1711	2953	3477	3643
February 2008	5720	1656	2926	3456	3709
March 2008	5500	1546	3036	3422	3776
April 2008	5530	1573	2870	3395	3754
May 2008	5500	1562	2760	3477	3665
June 2008	5420	1794	2815	3560	3643
July 2008	5480	1711	2843	3533	3709
August 2008	5395	1656	2732	3367	3671
September 2008	5495	1546	2650	3422	3560
Average	5521	1632	2859	3423	3673
Fibre (tonnes)					
Months	*Palm oil mill A*	*Palm oil mill B*	*Palm oil mill C*	*Palm oil mill D*	*Palm oil mill E*
October 2007	3240	972	1620	1944	2106
November 2007	3227	940	1782	1912	2171
December 2007	3188	923	1717	1993	2151
January 2008	3382	1004	1733	2041	2138
February 2008	3357	972	1717	2028	3177

March 2008	3227	907	1782	2009	2216
April 2008	3243	923	1685	1993	2203
May 2008	3227	917	1620	2041	2151
June 2008	3182	1053	1652	2090	2138
July 2008	3217	1004	1669	2074	3177
August 2008	3165	972	1409	1976	2155
September 2008	3224	907	1555	2009	2089
Average	3240	958	1662	2009	2323
Shell (tonnes)					
Months	*Palm oil mill A*	*Palm oil mill B*	*Palm oil mill C*	*Palm oil mill D*	*Palm oil mill E*
October 2007	1320	396	660	792	858
November 2007	1314	383	726	779	884
December 2007	1300	376	670	812	876
January 2008	1378	409	706	832	971
February 2008	1368	396	670	826	887
March 2008	1315	370	726	818	903
April 2008	1321	376	686	812	898
May 2008	1315	374	660	832	876
June 2008	1296	429	673	851	971
July 2008	1311	409	680	845	887
August 2008	1290	396	653	805	879
September 2008	1313	370	634	818	851
Average	1320	390	679	819	895

(Sources: Each selected palm oil mill)

3.1. Discriminant Analysis

Variation in the amount of solid waste was evaluated through DA. The DA applied on raw data consists of four type of solid waste. Four DFs was found to discriminate the five mills as shown in Table 1.Wilk's Lambda test showed that only the first two DFs is statistically significant as shown in Table 2. The relative contribution for each type of solid waste is given in Eq. (1) and (2)

$$Z1= -0.07\ EFB\ + 0.97\ potash\ ash\ -0.12\ fibre + 0.19\ Shell \quad (1)$$

$$Z2= -2.74\ EFB\ + 1.47\ potash\ ash + 0.77\ fibre + 1.25\ Shell \quad (2)$$

It is clear that potash ash exhibited the highest contribution in discriminating the five mills (Eq.1) and account for most of the expected variations of solid waste, while other wastes showed less contribution in explaining the variation between the mills. DA showed that the differences between the five mills can be mainly attributed to potash ash. Second DF showed different behavior from the first DF, since EFB exhibited the highest contribution, followed by potash ash and shell, while fiber contributed the lowest. Furthermore, 100% of the total variation between the five mills is explained by only two DFs as shown in Table 1. The quantity of the wastes depends on the quality of the FFB (Prasertsan and Prasertsan, 1996) .

Table 1.Eigen-value of DF for the five mills

Function	Eigenvalue	% of Variance	Cumulative %
1	202.11	99.80	99.80
2	0.44	0.20	100
3	0.01	0.00	100
4	0.00	0.00	100

a First 4 canonical discriminant functions were used in the analysis

Table 2 Wilks' Lambda for testing discriminant function validity

Test of Function(s)	Wilks' Lambda	Chi-square	df	P-value
1 through 4	0.00	309.92	16	<0.00
2 through 4	0.69	20.33	9	<0.02
3 through 4	0.99	0.46	4	<0.98
4	1.00	0.08	1	<0.78

According to Prasertsan and Prasertsan (1996), a high quality FFB will generate lesser waste than a low quality FFB. The amount of empty fruit bunches (EFB) generated from a low quality FFB are approximately 59% of the FFB whilst amount of fibre and shell generated are 13.9% and 10.6% respectively.

The classification matrix (Table 3) showed that more than 98% of the cases were correctly classified to their respective groups. The results of classification also showed that significant differences existed between the mills, which are expressed by in terms of two discriminant functions.

Table 3 Results of Classification results for discriminant analysis of the five mills

Mills	% correct	Predicted Group membership				
		A	B	C	D	E
A	100	12	0	0	0	0
B	100	0	12	0	0	0

C	100	0	0	12	0	0
D	100	0	0	0	12	0
E	91.7	0	0	0	1	11

a 98.3% of original grouped cases correctly classified.

3.2 Principal Components Analysis

Principal components analysis (PCA) was carried out on the data (4 variables) to compare the compositional patterns between the analyzed selected solid wastes and to identify the sources of variation. PCA yielded one component with Eigen-value >1, explaining 98.89% of the total variance in the data set. An Eigen-value gives a measure of the significance of the component; the component with the highest Eigen-value is the most significant and responsible in explaining large variation in the data. The Eigen-values for different components, percentage variance accounted, and cumulative percentage variances are given in Table 4. The PCA was actually performed on the correlation matrix between different types of solid waste.

The parameter loadings yielded from the PCA of the data are given in Eq.3.

$$PCA = 0.99 \ \ potash \ \ ash + 0.99 \ \ EFB + 0.99 \ \ Shell + 0.98 \ \ Fiber \qquad (3)$$

Eq.3 accounted for 98.85 % of the total variance and was positively correlated with all types of solid waste. This component may be termed as the average of all selected solid waste, since all solid wastes were highly contributed in explaining the total variation in the data. Extracting only one component indicates that the solid wastes are highly correlated between them.

Table 4. Extraction Method: Principal Component Analysis.

Componen	Extraction Sums of Squared Loadings

t			
	Total	% of Variance	Cumulative %
1	3.96	98.89	98.89

The relationship between component scores and the samples from different mills was studied to understand the behavior of selected solid wastes. Component scores for different mills are given in Figure1. It can be seen that mills A and E contributed positively, whilst the rest of mills contributed negatively this difference could be due to the level of solid waste in each mill. Palm oil mill A have the capacity of 1000 tonnes while palm oil mill E have the capacity of 650 tonnes. As discussed above, the amount of solid waste generated are depend on the capacity of the mill. Based on the capacity of mill A and E, it can be seen that the amount of solid waste generated in mill A was highest followed by mill E. Therefore mills A and E were contributed all positively.

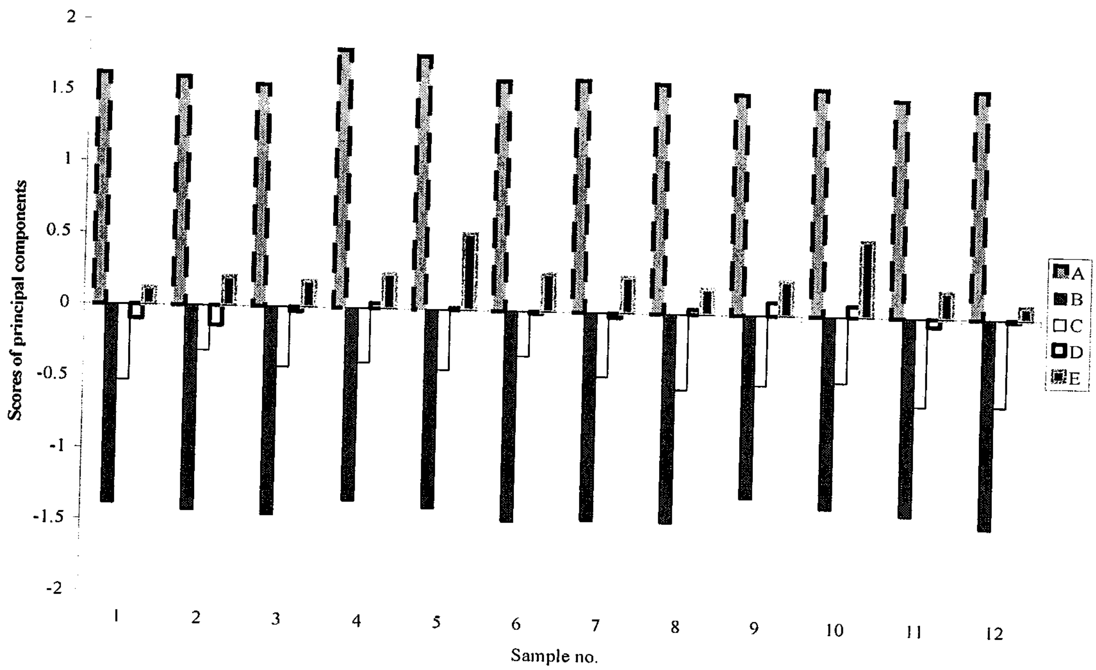

Figure 1. Scores of PCA for different samples of five mills

4. Conclusion

From the above results and discussion, it can be concluded that 98.89 of the total variance was explained by the average of all type of solid wastes included in the analysis as described by PCA. In addition, palm oil mill A and E exhibited a strong difference compared to the other mills studied, indicating a high amount of solid waste as supported by PCA. DA identified only two functions responsible for distinguishing the mills and it showed that the potash ash, EFB and shell were mainly responsible for large variations in the data, affording 98% correct assignation. Thus, DA helped to identify and understanding the source of variations. Therefore, the application of statistical techniques has been proven to be an effective tool for analyzing a huge and complex environmental data matrix.

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