Applying Mechanical Pre-Treatment and Landfill Mining Approach in Recovering Refuse Derived Fuel (RDF) from Dumpsite Waste: Thailand Case Study

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Abstract

This paper explores the possibilities of using basic mechanical pre-treatment principals and Landfill mining approach to recover the discarded plastics from Nonthaburi solid waste disposal site in Thailand. The excavated wastes from the dumpsite were characterized for their physical composition and chemical characteristics according to their disposal age. The composition of solid waste excavated from the site showed high plastic wastes content (25 to 45%) of total weight. The waste samples were first manually sorted to remove noticeable inert fractions and metallic components from the plastic wastes. The sorted wastes are then passed through a rotary trommel screen to remove finer particles and soil components. After trommel screening the plastic contents in the treated waste increased up to 83 – 90%. The sorted plastics were then shredded and blended with cassava starch in a proportionate ratio to produce RDF mainly targeted for industrial fuel. These were then formed into briquettes using a screw compactor. The maximum plastic content for an ideal densification of the briquettes were determined. The quality concerns and the characteristics of the fuel produced were in compliance with standards and acceptable for industrial use. This paper also looks into the economic aspects of producing such fuels.

Keywords

Dumpsite, Municipal Solid Waste, Rotary Trommel Screen, Refuse Derived Fuel, Calorific value.

1 Introduction

Open dumping is still the most commonly used for Municipal Solid Waste (MSW) disposal method in Thailand. At the moment, there are about five large open dumpsites in operation. Nonthaburi solid waste disposal site is one of the largest dumpsite in Thailand receiving about 750 tons of municipal solid wastes in 2005 from various municipalities and sub-district administrative organization in Nonthaburi province (USAID-ASIA, 2004).. Rapid exhaustion of available space for waste disposal is creating a crisis in solid waste management. This calls for a new approach involving the practice of waste minimization and recycling to conserve the remaining space in currently used disposal site. Waste mining also offers opportunity to provide new space at currently used and closed dumpsite and recycle of valuable materials. It evolves the excavation, transfer and processing of buried wastes taken from an active or closed landfill or dumpsite.

This will also help eliminating potential contaminant sources, cost reduction in post-closure monitoring and redevelopment of new sanitary landfill sites (HOGLAND ET AL., 2004; CES, 2004).

An initial investigation at Nonthaburi solid waste disposal site showed that high amount of combustible wastes mainly plastic is containing in dumped wastes. This finding indicates the possibility of recovering combustible materials for refuse derived fuel (RDF) production. RDF is a well-known alternative fuel produced from the combustibles in municipal solid wastes which are composed of waste plastic and other materials such as textiles, wood, soil, etc. compatibility exists for several reasons related to economic, environment, political and social aspects (CHANG ET AL., 1997).

To produce RDF as briquette, it is difficult to obtain strong briquette by screw compactor from plastic wastes without using binding agent. Well-known agents are molasses fibrous and oily organic wastes, sawdust, bitumen, pitch, sulphite liquor, starch, limestone, dolomite, etc. (YAMAN ET AL., 2001) Biomass usually has fibrous structure and contains oily sticky components which facilitate to form a more dense bulk should be increased to a degree at which transportation expenses becomes less and used facilitate ease of feeding for incineration (YAMAN ET AL., 2000).

In this study, solid waste open dumpsite in Nonthaburi province were determined for their physical/chemical characteristics, then plastic wastes were separated by workers and trommel screen to remove contaminated soil fraction, physical/chemical characteristics were determined. The separated plastics were shredded and mixed with cassava starch then formed into briquettes.

2 Municipal solid waste disposal site: Nonthaburi dumpsite

Nonthaburi solid waste disposal site is located at Moo 8, Klong Kwang sub-district, Sai Noi district, Nonthaburi province west of Bangkok, Thailand. The site is operated by Nonthaburi Provincial Organization Administration since 1982 stretched over an area of 68 rais (108,800 m^2) and receives approximately 750 tons of waste per day (USAID-ASIA, 2004). Schematic plan of the solid waste disposal site is shown in Figure 1. Prior to 2005, the incoming waste was continuously disposed in dumpsite area located in the middle of the site. In 1998, it was estimated that the total volume of the dumped wastes was approximately 1 million m^3 at this particular site.

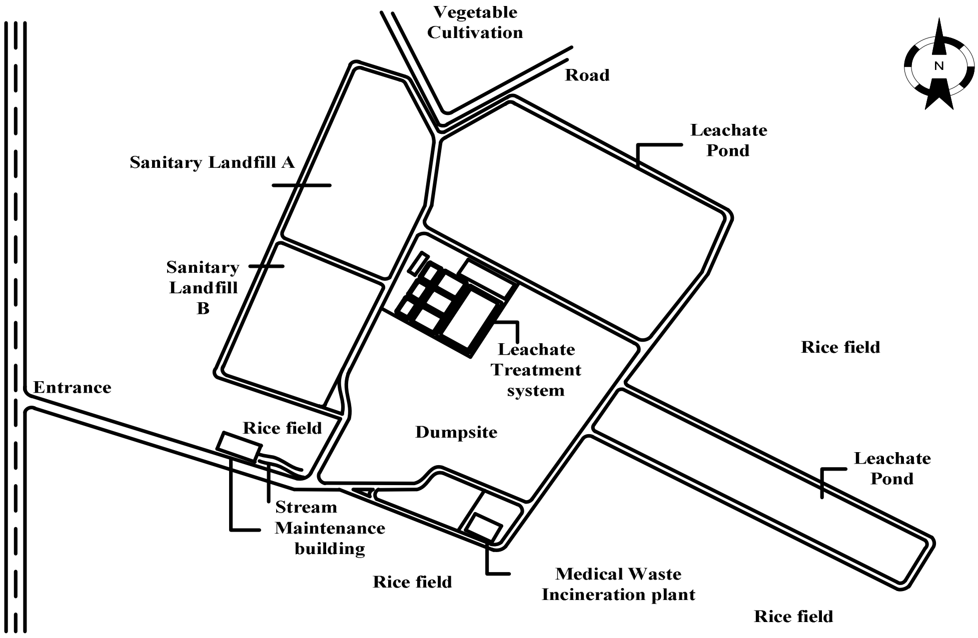

Figure 1 Schematic plan of Nonthaburi solid waste disposal site

3 Solid waste sampling

Solid waste dumped at Nonthaburi solid waste disposal site can be broadly classified into two major portions according to their disposal age, i.e. less than 7 years (sampling site located at the smaller portion of the dumpsite) and more than 7 years (sampling site located at the larger portion of the dumpsite). The samples were taken from both sites for the following experimental research. The waste samples were then collected and further characterized to determine its physical and chemical characteristics. For sampling purpose, a backhoe was used to excavate waste samples from five different sampling locations as shown in Figure 2. The wastes obtained from P-1 and P-3 sampling locations were 7 years old, P-2 and P-4 sampling locations had 3 waste layers of different ages (7 years old at the bottom, 5 years old in the middle and 2 years old at the top layer). The wastes at P-5 location were about 10 years old. Triplicate samples were taken from each sampling locations or layers according to their disposal ages.

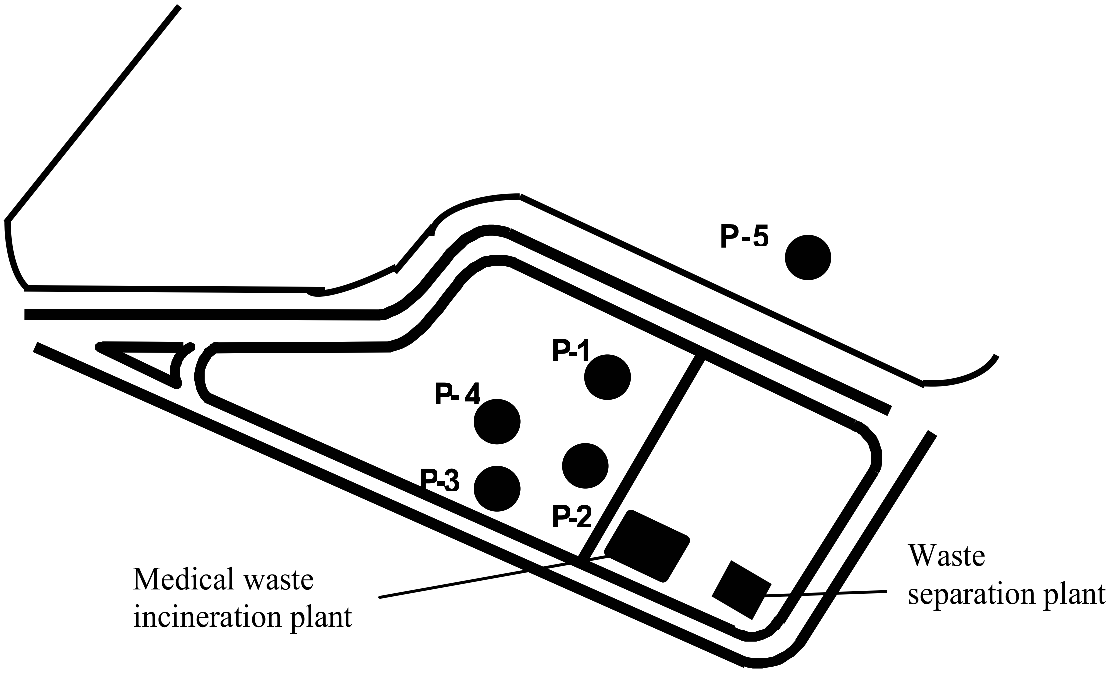

Figure 2 Waste sampling locations

4 Solid waste composition and characteristics

Analysis of the excavated waste showed no significant difference in the composition of solid waste between the sampling sites. Waste samples from P-1 and P-3 (both 7 years old waste) were chosen for this study. Soiled plastics, inert materials, wood, clothes and metals were the main components. Approximately 25-45% of soiled plastic, 28-57 % of soil like inert materials, 2-10% of wood, 2 -12% of clothes, and 2-5% of metal was observed in the excavated waste (Table 1). Small amounts of glass, ceramic, rubber, paper and foam were also found in the excavated waste. Figure 3 describes the average composition of the excavated waste samples.

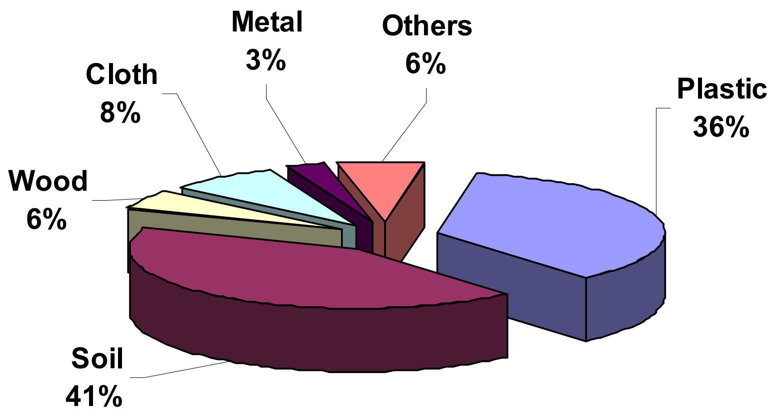

Figure 3 Average composition of excavated waste sample (% by weight)

Table 1 Solid waste composition of excavated wastes

MSW Fractions		Composition (% by wet weight)			
		2 years old	5 years old	7 years old	10 years old
Combustible	Plastic				
	- carry bags	20.63	11.92	23.38	17.37
	- other bags	8.91	4.53	10.54	6.59
	- other plastic	7.20	8.20	10.90	11.40
	Total	36.75	24.64	44.83	35.34
	Wood	7.66	3.42	9.77	1.20
	Paper	4.09	0.00	0.00	0.00
	Rubber	0.60	0.83	1.18	0.00
	Foam	1.75	0.55	0.88	0.60
	Clothes	11.51	7.45	10.21	1.80
Noncombustible	Soil/ inert	32.90	56.59	27.86	49.10
	Ceramic	1.19	0.83	0.73	2.99
	Glass	1.79	4.03	1.21	4.79
	Metal	1.79	1.66	3.34	4.19

5 Waste separation process

A pilot plant waste separation process was set-up at Nonthaburi solid waste disposal site. The separation process has a capacity of about 800 kg/h. Figure 4 shows the flow diagram of waste separation process. Solid wastes at 7 years disposal age was used in experimentation of the waste separation process. The waste separation process consists of manual separation as pre-treatment to remove larger and visible inert fractions which may upset the mechanical separation equipment (such as glass, rubber or large stones). The pre-treated wastes were then fed into a rotary trommel screen to separate plastic and soil-like materials.

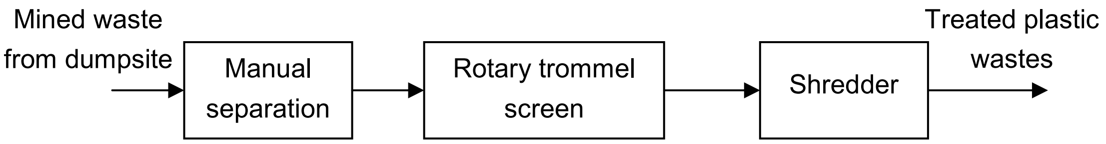

Figure 4 Flow diagram of waste separation process

The schematic of rotary trommel screen is shown in Figure 5. The length of trommel is 3m with diameter of 1m and 12.7 degree gradient. A 5-HP motor is used to rotate it in counter clockwise direction at 8 rpm. Two screen sizes were used, 25 and 50 mm. Three waste fraction could be obtained from this mechanical separation steps, i.e. > 50 mm plastic wastes, 25-50 mm soil-like fraction and <25 mm soil-like fraction. After separation, the separated plastic waste was shredded into small pieces (about 10 mm) by a plastic shredding machine (APM-3 HP-Pulley, Mitsubishi motor).

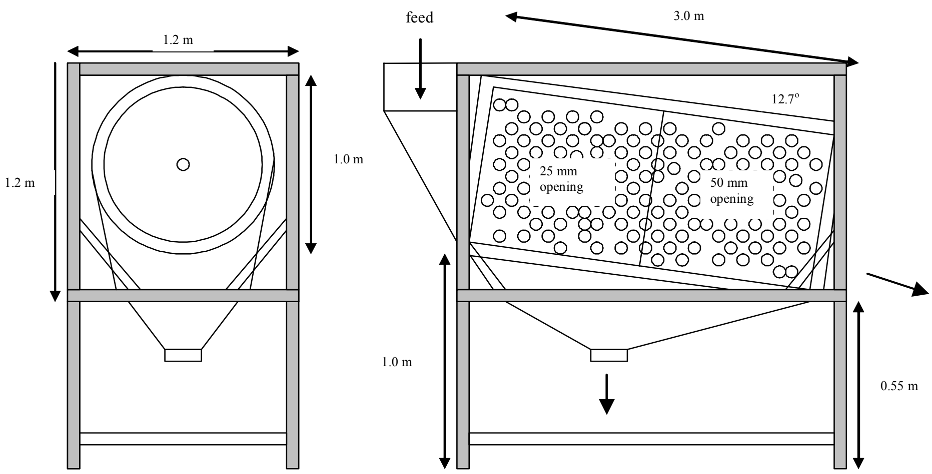

Figure 5 Schematic diagram of the rotary trommel screen

The waste separation in a rotary trommel screen recovered about 40% of incoming wastes at the feeding rate of 540-1080 kg/h. Total plastic contents in separated wastes were 82.9-89.7% (figure 6).

<25 mm **Between 25-50 mm** **> 50 mm**

Figure 6 Fractional distribution of waste samples after trommel separation

6 Particle Size Distribution

The excavated wastes samples were passed through the trommel and segregated into three different fractions according to their size. The distributions of waste fractions obtained from 13 samples are presented in figure 7. It could be observed that approximately 40% of waste fractions fall below 25 mm, about 25% lies between 25 mm to 50 mm and the rest is above 50 mm.

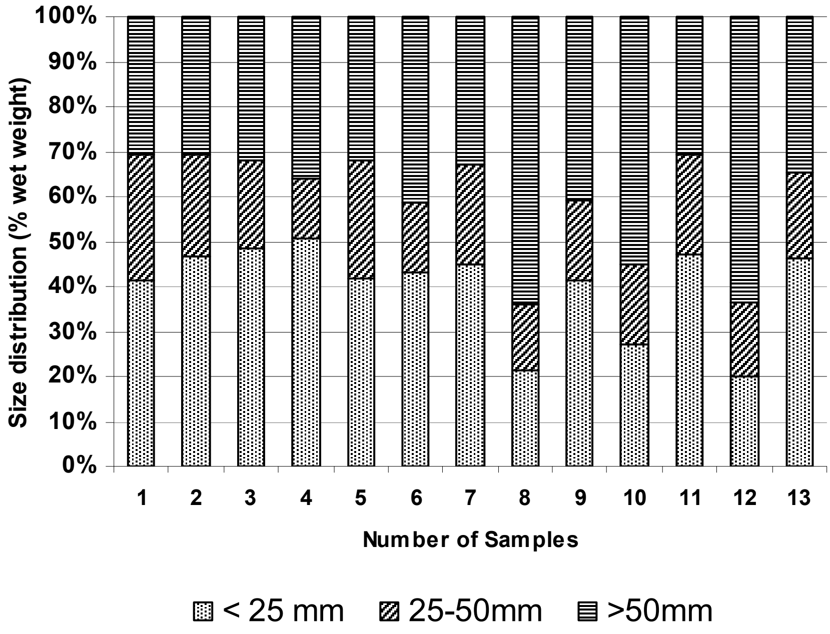

Figure 7 Size distribution of the sorted waste sample

The higher amount of 25 mm waste fractions is due to the presence of soil like inert materials and fully degraded organic matters which easily passes through the trommel opening. Those fractions between 25 and 50 mm which constitute about 25% of the sorted waste fractions are mostly pieces of ceramics, soiled plastics, cloth pieces, metal scraps and partially degraded matters. The remaining fractions (about 30-35%) are dominated by larger pieces (above 50 mm) of soiled plastics.

7 Chemical and Physical Characteristics of waste

The physical and chemical properties were examined from three different samples obtained from; raw excavated waste, manually separated and trommel separated are shown in tables 2 (a) and (b).

The plastic content in the dumpsite varied from 24.6-44.8%. Majority of plastic wastes was plastic carry bag. By analyzing these different waste samples, in most of the cases, the wood and soil components showed higher moisture content as compared to the rest. The moisture content of the plastic waste decreased during the separation process. The analysis showed that the bulk density and moisture content of the excavated waste varied from 20-50 % by its wet weight. The study also showed a significant decrease in the bulk density of the final sorted waste after trommel separation due to the removal of soil and inert particles after passing through the rotary trommel screen.

Decrease in the waste density also highlights the effectiveness of trommel separation and how the process rids off the soil and other inert attached to the plastics. The average density of the waste sample after trommel separation lies in the range of 50-60 kg/m^3. Since the final screened waste consist only plastics, it resulted in high calorific value and higher chlorine content.

Table 2 Physical and chemical characteristics of the waste

(a) Raw excavated waste

Type	Moisture (% by wet weight)	Volatile solid (% by dry weight)	Ash (% by dry weight)
Thin plastic bags (< 20 microns)	22.07	79.16	20.84
Plastic shopping bags (> 20 microns)	14.11	78.2	21.8
Plastic items	4.51	92.33	7.67
Wood	49.81	84.1	15.9
Rubber	5.8	69.33	30.67
Foam	9.23	72.89	27.11
Soil inerts	23.74	19.33	80.67

(b) Trommel separated plastic waste sample

Parameters*	Type of plastic		
	Plastic carry bags	Other plastic bags	Other plastics
Calorific value MJ/kg (dw)	40.99 ± 1.19	39.33 ± 3.36	33.38 ± 3.35
Chlorine (% dw)	2.51 ± 0.70	1.23 ± 0.84	3.95 ± 2.75
Sulfur (% dw)	0.21 ± 0.04	0.05 ± 0.04	0.04 ± 0.01
VS (% dw)	72.99 ± 10.56	83.48 ± 5.96	91.77 ± 6.44
Ash (% dw)	27.01 ± 10.56	16.54 ± 6.23	8.23 ± 7.84
Moisture (% w)	3.46 ± 2.24	1.49 ± 1.12	0.85 ± 0.38
Soil inerts ** (% ww)	38.12 ± 4.19	32.79 ± 4.68	8.67 ± 2.26

**Average value of 6 duplicate samples; ** The composition of soil like materials is 14.55 ± 4.16 and other materials is 5.86 ± 3.82*

8 Production of RDF Briquettes and its characteristics

The oversized plastic components obtained from the trommel screen are shredded and blended with different ratios of cassava starch. RDF briquettes production was carried out using a 5 HP screw compactor (Figure 8) after blending it with an appropriate ratio of cassava starch (Table 4). The cassava starch serves as a binding material. The final property of compacted RDF briquette depends on the composition of plastics and cassava starch. After the briquette production process, they were stored under ambient conditions for another 7 days prior to its final gasification study. The optimum ratio for the RDF briquette production was determined in terms of its final calorific value, sulfur and chlorine content.

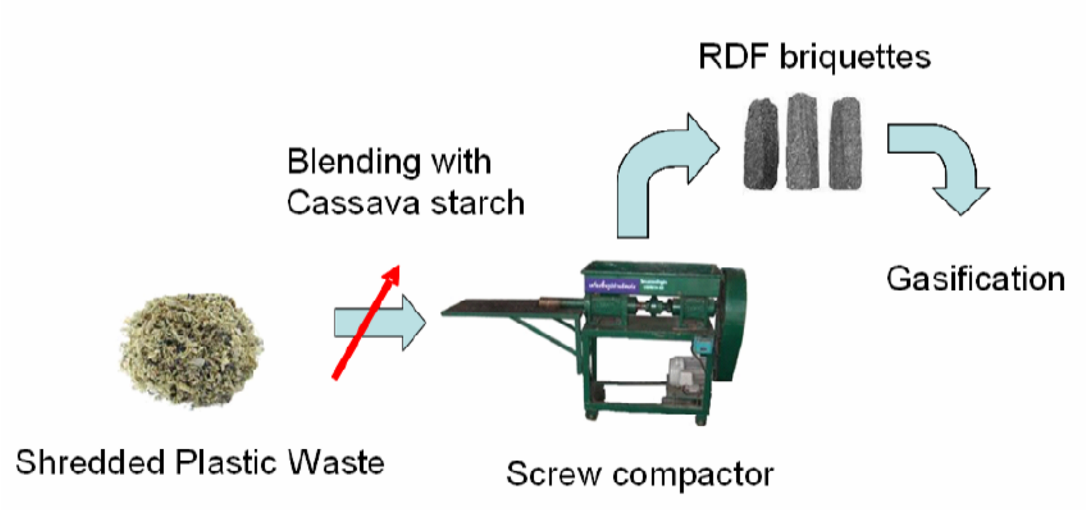

Figure 8 Steps involved in the production of RDF briquettes

Table 3 Chemical characteristic of RDF briquettes

Parameters*	Sample analysis (plastic : cassava starch)					
	1:0.8 (A)	1:1.0 (B)	1:1.2 (C)	1:1.4 (D)	1:1.6 (E)	cassava starch
Proximate Analysis						
moisture (%ww)	2.95±1.50	3.46±1.63	3.54±0.50	3.92±2.94	5.50±2.57	7.36±0.07
VS (%dw)	84.38±0.43	82.21±0.30	85.19±0.20	86.00±0.29	88.80±0.48	88.44±0.48
FS (%dw)	1.16±0.10	1.90±0.27	1.22±0.12	1.35±0.15	0.91±0.16	6.08±0.41
Ash (%dw)	14.46±0.34	15.89±0.28	13.59±0.28	12.65±0.43	10.29±0.38	5.49±0.08
CV (MJ/kg - dw)	25.97±0.48	23.84±0.96	21.86±0.86	22.84±0.68	23.16±0.96	16.72±1.18
Ultimate Analysis						
C (%dw)	46.88±0.24	45.67±0.17	47.33±0.11	47.78±0.16	49.33±0.27	49.13±0.27
H (%dw)	5.27±0.027	5.14±0.02	5.32±0.012	5.37±0.018	5.55±0.03	5.53±0.03
O (%dw)	46.76±0.56	47.94±0.03	46.75±0.71	46.20±0.14	44.29±0.51	45.16±0.31
N (%dw)	0.052±0.09	0.11±0.018	0.062±0.02	0.076±0.01	0.084±0.02	0.081±0.02
S (%dw)	0.19±0.029	0.16±0.021	0.16±0.031	0.14±0.023	0.14±0.012	0.047±0.01
Cl (%dw)	0.85±0.41	0.99±0.14	0.97±0.62	0.44±0.31	0.61±0.40	0.048±0.01

** Average values of triplicate samples*

Although the average chlorine content in the produced RDF briquettes (does not meet the European Union for Responsible Incineration and Treatment (EURITS) limit of 0.5% it still fulfills the specification for co-incinerating as secondary fuels in cement plants in Sweden and Finland (where Chlorine content < 1%). RDF briquettes produced are also in compliance with the (EC-DGE, 2003) standards for RDF composition and properties produced from MSW.

Even though no Asian standards sets against using RDF briquettes produced from MSW, but with respect to European standards and guidelines, the optimum blending ratio achieved for this study was noticed in samples A and B (Figure 9).

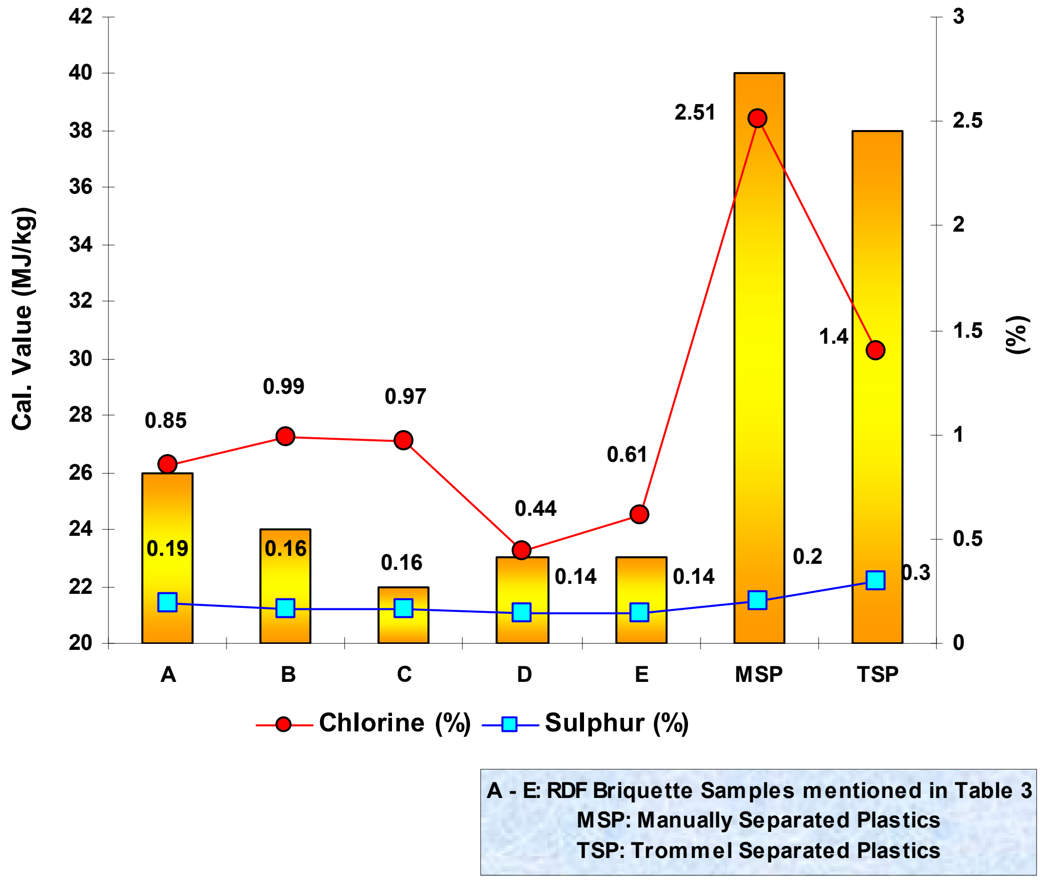

Figure 9 Chemical characteristics of RDF briquettes

Sample A attained a calorific value of 26 MJ/kg (dry weight) with sulfur and chlorine contents of 0.19% (dry weight) and 0.85% (dry weight), respectively.

9 Cost of RDF production and energy recovery

The cost of RDF production was estimated based on pilot-scale plant of 580 kg solid waste per day capacity (8 hours operation per day). The preparation of RDF involves 2 main preparation steps, i.e. plastic waste separation and RDF briquette production.

RDF could be produced at 328 kg per day with production cost of 2,750 THB per day (1 USD approx. 35 THB) or 8.39 THB per kg of RDF based on optimum plastic: cassava starch ratio of 1:0.8. When considering RDF conversion to energy, the produced RDF could be converted to energy of 9,080 MJ per day or 2,523 kWh per day with total cost of 4,484 THB per day or 1.69 THB per kWh. Table 4 shows the comparison of energy production from RDF with other fuel.

Table 4: Cost of electricity production (2,523 kWh) from different types of fuel

Fuel type (unit)	Factor (unit/kWh)	Required fuel (unit)	Total cost (THB)	Energy cost (THB/kWh)
RDF (kg)	0.13	328	4,484	1.7
Coal (kg)*	1.00	2,523	1,262	0.50
Natural gas (cf)*	8.14	20,537	5,234	2.07

1USD approx. equals 35 THB (March 2007)

*Source: Department of Mineral Fuels, Ministry of Energy (Thailand)

According to the typical electricity production cost of Thailand and the pilot scale analysis, the energy production using RDF briquettes showed higher cost compared to coal.

10 Conclusion

This study investigated that, principals of mechanical pre-treatment and landfill mining are the most conducive method to recover combustible fractions for RDF production. Backhoe was used to mine the waste samples prior to passing it through a trommel screen. The elimination of soil and inert materials from the waste fractions and dominance of plastic components in the final screened sample is evident to signify the effectiveness of this approach. It was found that the best way for the production of RDF briquettes is by blending the shredded plastic waste with cassava starch. The ideal densification of the RDF briquettes in compliance with emission standards were met at blending ratios of 1:0.8 and 1:1 (*Shredded Plastic: Cassava starch*). The RDF briquettes produced from this approach showed promising results (in terms of its calorific value) for its application as a secondary fuel for co-incineration in cement and brick kilns.

11 Literature

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