RDF Production Potential of Municipal Solid Waste

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Abstract: *The composition and characteristic of excavated solid waste from Nonthaburi Municipal solid waste (MSW) dumpsite was studied to evaluate the potential of refuse derive fuel (RDF) production. The composition of solid waste mainly consists of 41.5% plastic and 30.9% soil. The recycle of plastic waste from the Nonthaburi dumpsite for RDF production was therefore possible. The results of calorific value analysis of around 29.5 MJ/kg indicates the high heat value derived from solid waste and it's potential to be used as RDF. However, the moisture, ash content and heavy metal contaminated in the excavated solid waste exceeded the standard for RDF. In this regard, the trommel screen (with mesh size of 25mm and 50mm) was used to separate the soil fraction other components in waste. Almost 82% of plastic waste could be classified as the overflow waste and recovered, whereas 55% of soil content was removed as underflow waste after screening. The purity of recovered plastic however was still low after screening. Therefore, further separation process is necessary to increase the purity of plastic waste for RDF production.*

Keywords: Dumpsite, Municipal Solid Waste, Refuse Derived Fuel, Plastic, Heavy Metals, Calorific Value

1. INTRODUCTION

Open dumping is a common method of municipal solid waste (MSW) disposal in many developing countries. The MSW is generally disposed into an excavated land or open area without any precautionary measures. Due to the lack of control on the type of waste disposed into dumpsites, various kinds of household hazardous waste are disposed. The degradation of MSW along with household hazardous waste in the dumpsite leads to the risk on human health and the environment. The study on the MSW degradation along with heavy metals mobilization in landfill showed that most heavy metals are still retained in the stabilized landfill. In addition, the changing condition within the landfill such as pH and redox potential as well as water intrusion into the landfill is able to activate the heavy metals leaching into the environment [1, 2]. Thus, landfill reclamation is proposed to mitigate or reduce the environmental problem from stabilized landfill. Landfill reclamation is not a new activity to restore our environment as there were many landfill reclamation projects has been already reported such as the Naples landfill, Edinburgh landfill and Frey farm landfill [3].

The stabilized landfill is excavated and the soil content from the waste is separated. The recovered soil is then reused as cover soil in the landfill whereas the combustible waste fraction is delivered to the waste-to-energy (WTE) facility. Finally, the landfill site is improved and used again for waste disposal. Generally, 85-95% of soil, 70-90% of ferrous steel, and 50-75% of plastic can be recovered from landfill mining [4]. The refuse derived fuel (RDF) is one of the products of recycling combustible waste fractions from MSW to be used as fuel for stream or electricity production. To produce RDF, the heat value and chemical constituents especially heavy metals and chloride are normally taken into account to assure the RDF quality in order to avoid the environmental problem that may result from incineration [5].

In this study, the feasibility of RDF production from Nonthaburi dumpsite is presented. The Nothaburi dumpsite is situated at Sai Noi district, Nonthaburi, Thailand. The dumpsite has been operated since 1982 to accommodate the MSW generated in Nonthaburi province. It has been found that approximately 260 tons/d and 180 tons/day MSW was generated from Nonthaburi and Parket municipality [6]. Evaluation of RDF production potential on Nonthaburi MSW dumpsite was carried out to determine the recycling potential of the dumped MSW as RDF. Generally, the solid waste deposited in the dumpsite consists of various waste ages. The 3-7 years old dumped MSW was selected to determine the potential of degraded waste fraction to be recycled as RDF for energy production.

2. METHODOLOGY

2.1 Solid waste sampling and classification

The backhoe excavator machine was used to excavate the 3m depth of 4 sampling points on the dumpsite. Approximately 150 kg of solid waste was then collected from every 1m depth interval. After collecting the samples, the bulk density of excavated waste was measured. The air dried excavated solid waste was then manually classified into combustible, noncombustible and hazardous waste fractions. Moreover, the analysis of size distribution of air dried solid waste was conducted by the use of trommel screen with mesh size of 25mm and 50mm. Three categories of solid waste could be obtained after the trommel separation process they are: overflow waste size >50mm, medium size waste 25-50mm, and small size waste <25mm. The composition of solid waste from each category was also classified. The size distribution analysis of solid waste is presented in figure 1.

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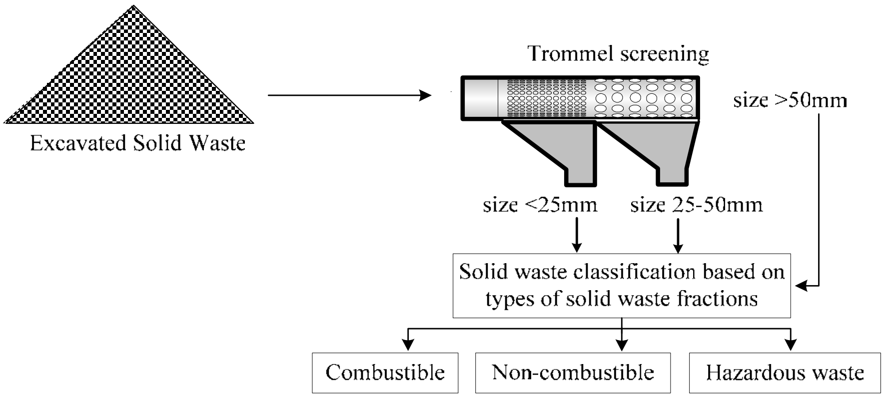


Fig. 1 Size distribution analysis of solid waste

2.2 Solid waste analysis

The physical and chemical characteristics of unsorted waste were analyzed. The unsorted waste was sampled and air dried for moisture content analysis. The dried solid waste samples were grinded and subjected to residual moisture and ash content analysis. The calorific value of air dried solid waste was analyzed by using Bomb Calorimeter (CAL2K-CAL2k.ECO). In addition, 1-2 g of air dried samples was digested with nitric, sulfuric and hydrofluoric acid for Mn, Cr, Cd, Pb, Ni, Zn and Cu analysis. The concentration of Mn, Cr, Cd, Pb, Ni, Zn and Cu in the samples solution was then quantified by using the ICP-OES (PerkinElmer Optima 2100DV), whereas the concentration of Hg in solid waste samples was analyzed by Cold-vapor system. The overall samples preparation for analysis as well as physical, chemical and heavy metal analysis method of solid waste in this study follows to the American Society for Testing and Materials standard [7].

3. RESULTS AND DISCUSSION

3.1 Solid waste classification

Table 1 describes the solid waste composition of Nonthaburi MSW dumpsite in comparison with other dumpsites. The results revealed that the solid waste composition in the dumpsite was mainly consists of soil fraction and plastic material. Small fractions of textile, wood, rubber, paper, metal, glass, etc. are also contained in the waste. Furthermore, the hazardous waste components in the dumpsite could not be detected based on this classification. Based on the data presented on table 1, high fraction of plastic waste materials can be found in Nonthaburi dumpsite which is much higher compared to Pathumthani dumpsite and even in Kodungaiyur and Perungudi dumpsites in India. This is maybe due to the high influx of plastic used contains in the waste as well as the degree of degradation and transformation of organic matter within the dumpsite. As according to PCD (2004) [6], the average composition of plastic and food waste dumped at Nonthaburi is 20% and 65%, respectively. This information suggest as the representative composition of original MSW dumped into the dumpsite. However, It has been suggested that approximately 15-40% of the original matter dumped into the landfill can be degraded and lost from the landfill via leachate, gas and soil production. On the other hand, 14-68% of original organic matter is still remained in the landfill after 8 years of degradation period [8]. As the result of solid waste classification, the average soil fraction of around 31% is therefore found in Nonthaburi dumpsite. This soil fraction is relatively low compared with other dumpsites of Pathumthani and Kodungaiyur. According to the result of study, the high plastic material contains in dumpsite therefore is possible to be recycled as RDF.

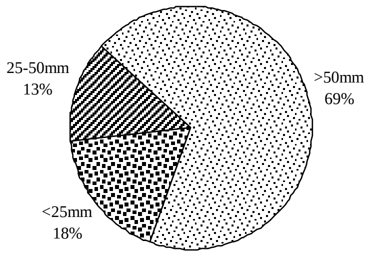
Table1 Solid waste composition from Nonthaburi dumpsite

Waste composition		Nonthaburi		Pathumthani Thailand [9] (% w/w)	Kodungaiyur, India [10] (% w/w)	Perungudi, India [10] (% w/w)
		Range (%w/w)	Mean (%w/w)			
Combustible	Plastic	20.0-65.0	41.5	11.2	1.9	11.0
	Wood	2.0-25.0	9.0	1.0	0.5	11.6
	Textile	6.0 -16.0	10.0	0.9	0.6	2.3
	Rubber	ND-5.8	1.0	1.2	0.5	14.5
	Paper	ND-6.0	0.7	ND	NA	NA
	Foam	ND-2.5	1.0	ND	NA	NA
	Food	NA	NA	1.5	NA	NA
Non-combustible	Stone	ND-2.5	0.9	1.2	28.3	18.5
	Glass	ND-4.5	1.8	9.2	0.4	0.8
	Metal	ND-8.5	3.0	1.8	0.1	0.2
	Soil	5.0 -68.0	30.9	72.0	67.8	40.1
	Hazardous waste	ND	ND	NA	NA	NA

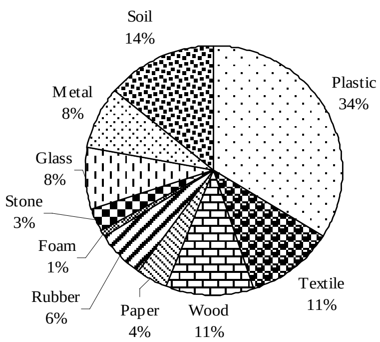
Note: NA = is not analyzed; ND = Non-detectable

3.2 Size distribution of waste fraction

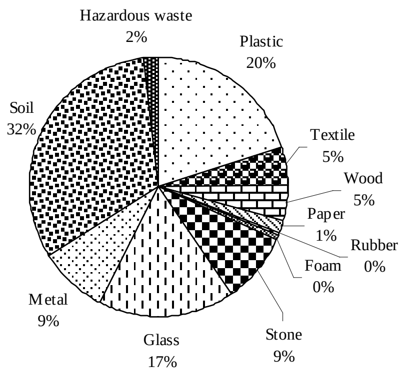
The result of size classification of solid waste revealed that most of waste fraction is of size >50 mm. According to the size distribution of solid waste as depicted in figure 2, approximately 69% of total solid waste fed into the trommel screen could be recovered as the overflow fraction, whereas 13% and 18% was removed into the underflow having a size of 25-50 mm and <25 mm, respectively. The additional classification of waste composition found that the waste size <25mm was mix of soil, fine particle, wood, broken glass, metal, and little amount of plastic waste was found in this category. In the case of the waste of size 25-50 mm, approximately 67% of total waste recovered was incombustible waste. The small fractions remaining were 31% combustible waste and 2% hazardous waste (fig. 2c). For the overflow waste classification (>50 mm), the solid waste received includes 34% plastic, 11% textile and wood, 6% rubber, 4% paper and 1% foam. The average 14% soil, 8% metal/glass, and 3% stone, however, was still remained in the overflow fraction. By using the trommel screen, it is therefore revealed that almost 55% of total soil in the excavated waste could be classified as underflow waste size <50 mm and removed from the waste stream. The performance of trommel screen used in this study, however is below the normal range of soil removal efficiency as suggested to be 85-90% [4]. In this study, the plastic waste was recovered using trommel screen, according to the calculation; the efficiency of the trommel screen to recover the plastic fraction is approximately 82%. In this case, the efficiency of the trommel screen to recover plastic materials is satisfactory; however the purity of plastic material is relatively low due to considerable fraction of soil, metal, glass, wood, textile and other fractions contain in overflow plastic material. Savage, et al [4] suggested that the purity of plastic waste to be recovered from the MSW landfill should be 70-90%. The additional separation process therefore should be added in order to increase the purity of plastic waste recovered from dumpsite as RDF.



(a) Size distribution of the excavated waste after trommel screening



(b) Waste compositions after screening (size >50mm)



(c) Waste composition after screening (size 25-50mm)

Fig. 2 Size distribution and composition of excavated waste fraction from trommel screening

3.3 Characteristic of solid waste

The physical and chemical characteristics of solid waste in comparison to the quality standard of RDF and the quality of the waste to be co-combusted in the cement plant are described in table 2. The measured bulk density of the waste in Nonthaburi dumpsite is in the range of 225-412 kg/m^3 is relatively low compared to the waste in Pathumthani dumpsite having a bulk density in the range of 780-880 kg/m^3. The result may be due to the high concentration of low density plastic material in the waste of Nonthaburi dumpsite, whereas the concentration of soil content is relatively low. The waste in Pathumthani dumpsite which showed higher waste bulk density is due to the high soil content of 70-75% [8]. Moreover, the average dry density of Perungudi and Kodungaiyur dumpsite was 960 kg/m^3 and 1100 kg/m^3 at 40% and 67.8% soil content, respectively [10]. Age of waste of dumpsite is also a factor influences soil content [10]. The calorific value analysis of unsorted solid waste was carried out to determine the available heat value. The average 29.5 MJ/kg dry weight was obtained from waste deposited in the dumpsite indicating their high potential to be used to WTE. The typical calorific value of plastic waste was ranged 28-37 MJ/kg [11]. Additionally, 23-27 MJ/kg was derived from Pathumthani dumpsite which 29-30 MJ/kg dry weight could be received from plastic waste [8].

However, the result of ash and moisture content analysis of the excavated waste in Nonthaburi dumpsite exceeds the allowable concentration of the RDF standard. The similar moisture and ash content analysis result was also found in Pathumthani dumpsite with 20-35% moisture and 50-90% ash [8]. Furthermore, the environmental impact from the recycling of solid waste to produce energy was considered through the concentration of heavy metals (Zn, Cu, Mn, Cr, Cd, Pb, Ni, and Hg) as described in table 2. The result of heavy metals concentration present in the waste from Nonthaburi dumpsite in comparison with the quality standard of RDF revealed that Cd, Ni, Zn, and Cu are among the heavy metals that exceeds the standard value. Moreover, in comparison with the standard of waste to be co-combusted in cement plant indicated by the European Union for Responsible Incineration and Treatment of Special Waste (EURIST) revealed that Mn, Cd, Zn, and Cu exceeds the standard value. This suggests that excavated waste from Nonthaburi dumpsite should not be directly used for combustion to generate fuel since the concentration of heavy metals is higher than the quality standard. Also, the ash, moisture content of the waste needs to be improved as it was higher than the standard value. In this regards, it is necessary to subject the excavated waste to various separation process to improve the quality of combustibles by removing the high soil fraction in the waste which will lead also in moisture content reduction of the waste.

Table 2 Characteristic of waste excavated from the MSW Dumpsite

Parameter	**Unit**	**Characteristic of MSW dumpsite**		**Refuse derived fuel quality standard [12]**		**Quality of waste for co-combustion in cement plant designed by EURIST [12]**
		Range	**Mean ± SD**	**Italy**	**Finland** [a]	
Density	kg/m^3	225.0-412.0	314.2 ± 70.5			
Calorific value	MJ/kg	20.2-40.4	29.5 ± 8.0	15.0		
Ash	%	36.5-79.9	59.8 ±13.0	20.0		
Moisture	%	28.6-59.5	47.0 ± 9.0	25.0		
Mn	mg/kg	100.0 -353.0	215.2 ± 80.5	400.0		200.0
Cr	mg/kg	57.5 -186.0	87.5 ± 39.0	100.0		200.0
Cd	mg/kg	0.9 -38.0	5.5 ± 10.5		5.0	10.0
Pb	mg/kg	13.2 -127.0	47.8 ± 33.0	200.0		200.0
Ni	mg/kg	24.2 -94.0	48.5 ± 21.5	40.0		200.0
Zn	mg/kg	275.4-586.5	458.5 ± 110.0	500.0		500.0
Cu	mg/kg	118.8-544.6	254.0 ± 119.5	300.0		200.0
Hg	mg/kg	0.2 -0.5	0.4± 0.1		0.5	2.0

[a] Standard RDF quality class III

4. CONCLUSION

The classification of solid waste excavated from the Nonthaburi dumpsite revealed that the waste deposited is mainly consists of plastic and soil fraction. Based on the laboratory analysis result, the waste deposited in the dumpsite contains sufficient calorific value (29.5 MJ/kg) for the energy production. However, most of the heavy metals contained in the excavated waste exceed the quality standard for RDF and the quality indicated by EURIST for possible co-combustion in cement kilns. Moreover, the moisture and ash content in the waste also exceeds the RDF standard. In this view, the excavated waste therefore should not be directly used for fuel generation. However, it can be processed to increase its quality prior to fuel generation.

Recycling of the combustible waste to produce RDF is possible using the waste from Nonthaburi dumpsite. This recycling activity promotes waste to energy concept while maximizing the use of resources. The high percentage of plastic (20-65%) contained in the excavated waste indicates that it is possible to recycle the plastic into RDF product. The results of various analyses to measure the quality of the plastic in the waste suggested that it is necessary to subject the waste for separation process to remove the soil and improve the moisture content. Trommel screen is employed in this study to separates the waste into several fractions. The approximately 82% of total plastic waste fed into the trommel is of size >50 mm and could be recovered at the end of separation process. At the same time, 55% of soil contain in the excavated waste classified as underflow waste (<50 mm) could be removed by the use of trommel screen. However, due to the 34% purity of plastic waste recovered from the trommel which is considered low, further separation processes is therefore necessary to improve the plastic quality.

5. ACKNOWLEDGMENTS

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Outline

- Introduction
- Solid Waste Sampling and Analysis
- Result and Discussion
- Conclusion

Introduction

- Municipal solid waste (MSW) disposal into the dumpsite (without any precautionary measure)
- Disposal of household hazardous waste (contained in MSW stream) into dumpsite
- Leaching of toxicants into the environment
- Human health and environmental impact

Landfill Reclamation

- Stabilized waste is excavated and separate any soil fraction
- Recovering of the combustible waste into waste-to–energy plant or the refuse derived fuel (RDF) production

Parameter	RDF standard		EURIST
	Italy	Finland	
Moisture (%)	25.0		
Ash (%)	20.0		
Calorific value (MJ/kg)	15.0		
Mn (mg/kg)	400.0		200.0
Cr (mg/kg)	100.0		200.0
Cd (mg/kg)		5.0	10.0
Pb (mg/kg)	200.0		200.0
Ni (mg/kg)	40.0		200.0
Zn (mg/kg)	500.0		500.0
Cu (mg/kg)	300.0		200.0
Hg (mg/kg)		0.5	2.0

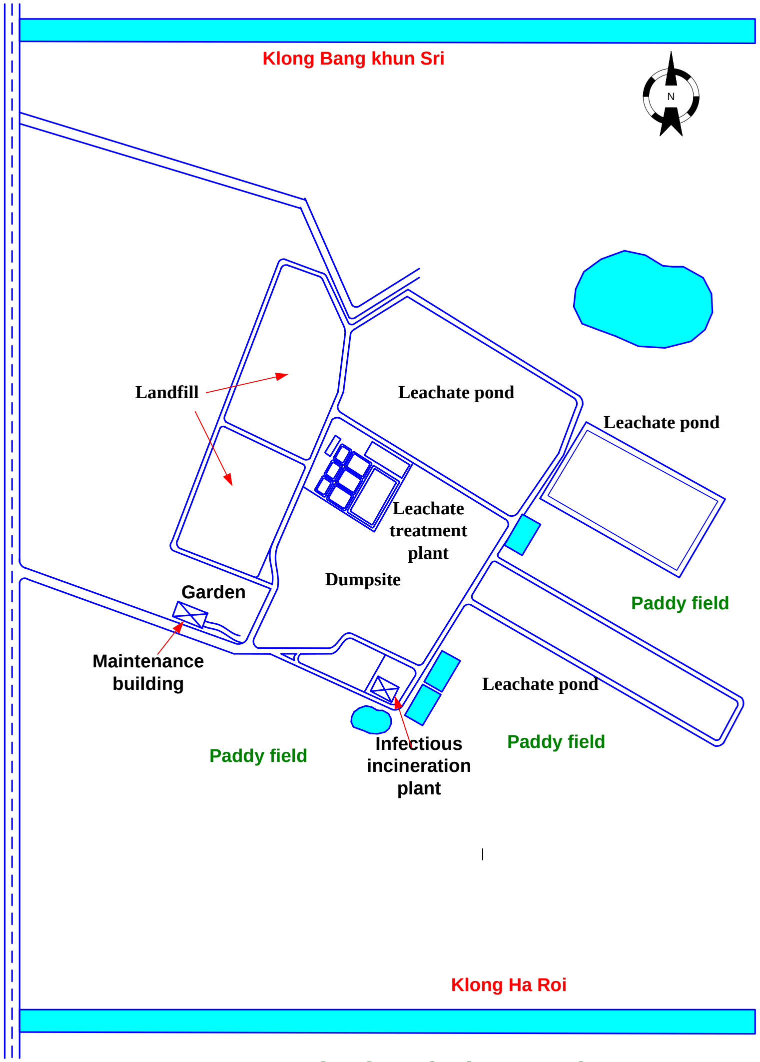
Standard quality of RDF and waste co-combusted in cement plant

EURIST = European Union for Responsible Incineration and Treatment of Special waste

Objective of the Study

- To determine the recycling potential of dumped MSW in Nonthaburi dumpsite as RDF

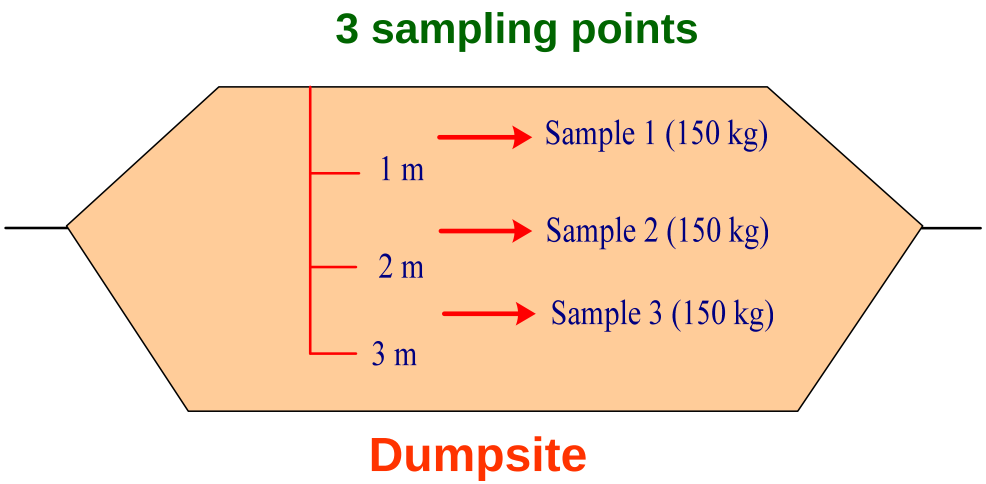
- Operated since 1982
- Incoming waste = 900 tons/day (260 tons and 180 ton)
- 20% plastic and 65% food waste



Nonthaburi dumpsite

Methodology

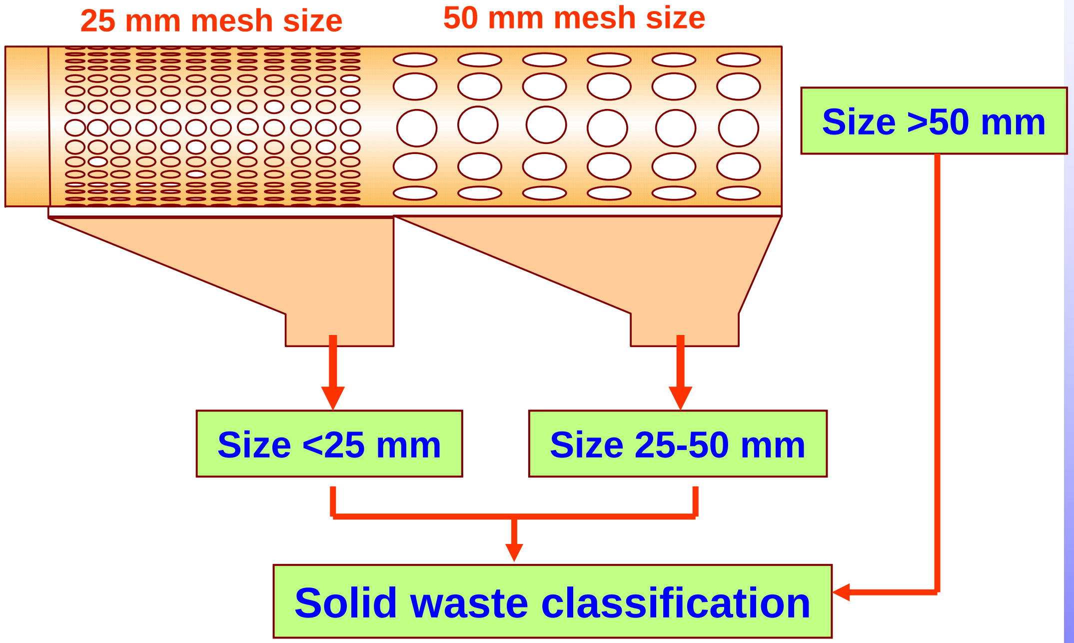
1. Solid waste sampling and analysis



- Waste composition (combustible, noncombustible and hazardous waste)
- Physical characteristic (bulk density, moisture, ash, calorific value)
- Heavy metals concentration (Mn, Cr, Cd, Pb, Ni, Zn, Cu, Hg)
- Size distribution of solid waste

Methodology

2. Size distribution analysis of solid waste



Dimension: 1 m diameter x 3 m length

Inclination: 12.7°

Rotational speed: 8 rpm

Motor power: 5 hp

Capacity: 500 kg/h

Result and Discussions

1. Solid waste composition

Composition		% (w/w)
Combustible	Plastic	41.5
	Wood	9.0
	Textile	10.0
	Rubber	1.0
	Paper	0.7
	Foam	1.0
	Food	1.0
Non-combustible	Stone	0.9
	Glass	1.8
	Metal	3.0
	Soil	30.9

- **High percentage of plastic waste of Nonthaburi dumpsite (41.5%)**
  - 11.2% of Pathumthani dumpsite, Thailand
  - 1.9% of Kodungaiyur, India
  - 11.0% of Perungudi, India

- **Relative low concentration of soil fraction**
  - 72% of Pathumthani, 67.8% Kodungaiyur and 40.1% of Perungudi

Result and Discussions

2. Physical characteristics of solid waste

Parameter	Range	Mean
Density (kg/m^3)	225.0- 412.0	314.0
Calorific value (MJ/kg)	20.2-40.4	29.5
Ash (%)	36.5-79.9	59.8
Moisture (%)	28.6-59.5	47.0

3. Heavy metals concentration of solid waste

Heavy metal (mg/kg)	Range	Mean
Mn	100.0 – 353.0	215.2
Cr	57.5 – 186.0	87.5
Cd	0.9 – 38.0	5.5
Pb	13.2 - 127.0	47.8
Ni	24.2 – 94.0	48.5
Zn	275.4 – 586.5	458.5
Cu	118.8 – 544.6	254.0
Hg	0.2 – 0.5	0.4

Result and Discussions

✓ Relative low density of Nonthaburi dumpsite (314.2 kg/m^3) compare with other dumpsite

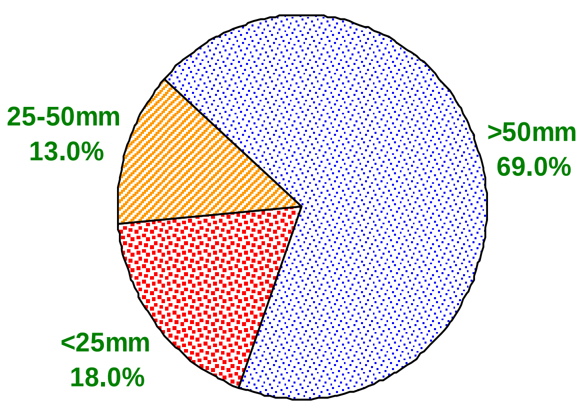
✓ Relative High heating value is available from waste (29.5 MJ/kg)

Parameter	Pathumthani	Perungudi	Kodungaiyur
Density (kg/m^3)	780-880	960	1100
Calorific value (MJ/kg)	23.0-27.0	-	-
Ash (%)	50-90	-	-
Moisture (%)	20-35	-	-

- Ash and Moisture content exceed the RDF standard
- Cd, Ni, Zn, Cu concentration is > RDF standard
- Mn, Cd, Zn, and Cu concentration is > standard of waste co-combusted in the cement plant

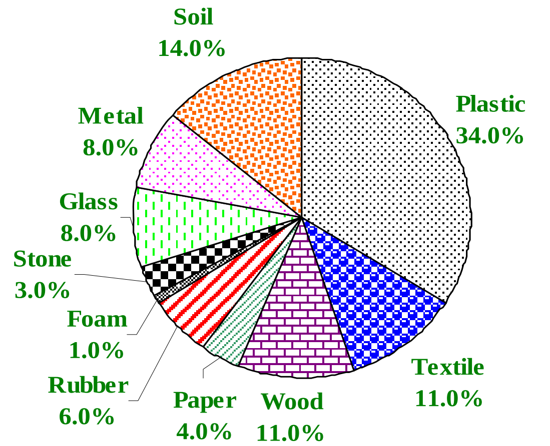
Result and Discussions

4. Size distribution and composition of excavated waste after trommel screening

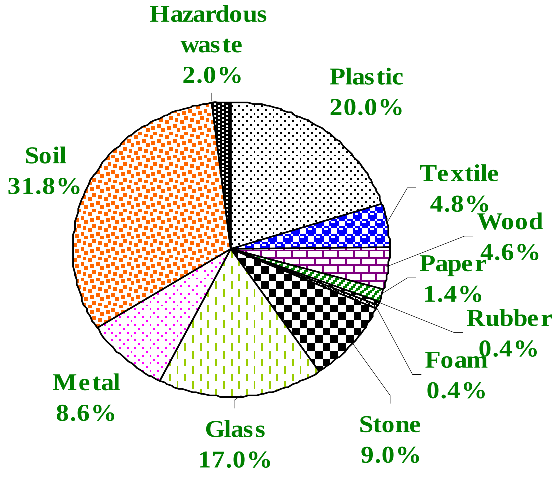


Size distribution of excavated waste

Size < 25mm



Size > 50mm



Size 25-50mm

Conclusion

- Waste composition in the Nonthaburi dumpsite is mainly consist of plastic and soil fraction
- Sufficient calorific value could be available from the waste for energy production
- Excavated waste should be processed to improve its quality prior to fuel generation
- Recycling of the plastic waste as RDF is possible for Nonthaburi dumpsite
- Waste separation process is necessary to remove the soil and improve the moisture content of segregated waste

Conclusion

Waste segregation by using trommel screen

- 55% of soil fraction is removed into the underflow which is below the normal range (85-90%)
- 82% of plastic waste with 34% purity is recovered from the trommel separation a overflow waste size > 50mm
- Further separation process is necessary to improve the plastic waste quality

Thank you for your kind attention