WASTE MANAGEMENT

What is the choice :

LAND DISPOSAL OR BIOFUEL?

PROFESSOR DR. AZNI IDRIS

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ABSTRACT

Many cities in developing Asian countries are facing serious problems in managing their municipal solid wastes as annual waste generation increases in proportion to the rise in population and urbanization. Asian countries with greater rural settings produce more organic waste such as kitchen wastes and less of recyclable items such as paper, metals and plastics. The method of disposing wastes using landfill poses a serious environmental threat which requires innovation and more research has to be carried out to solve this issue. New challenges faced by local authorities are related mainly to finding the best option for managing the problems and costs of collection and disposal of solid wastes in a growing city. With the global scenario of escalating cost of fuel prices, municipal solid waste is seen as a potential resource for our renewable energy project. There is growing interest in the utilization of solid waste as biofuel to produce electricity. Various technologies in converting the waste material into biofuel are made available, which may change the landscape of today's waste management, from landfill disposal to resource recovery.

Biofuel economy has steered our thoughts towards the conversion of such unwanted materials into valuable energy feedstock, which the world is now seriously moving towards. With the emergence of new technologies for conversion of wastes into biofuel, be it biomass or biogas, the options are now very clear. The Biofuel option can be the best strategy as long as our policies are targeted toards achieving sustainable development as the ultimate goal.

INTRODUCTION

Many cities in developing Asian countries are facing serious problems in the management of solid wastes. As annual waste generation increases in proportion to the rise in population and urbanization, issues related to disposal become even more challenging as more and more land is needed to cater for the ultimate disposal of these solid wastes. Several major cities in developing countries have reported problems with existing landfill sites. [1, 2]

Rapid development and changing lifestyles in growing cities have also changed waste composition from mainly organic or putresible to plastics, paper and packaging materials that are complex in nature. For instance, Kuala Lumpur produces about 3,000 tonnes of solid wastes per day of which more than 50% is food or organic material. Storage and collection systems are becoming more sophisticated and costly as the types and sources of waste produced are getting more diversified and the availability of disposal sites within the collection areas is becoming limited.

As a result of the huge amount of waste generated, many developing countries are facing serious problems in disposal of their wastes. It is becoming more difficult to find landfill sites within the collection areas and at the same time, the remaining operating life of existing sites is becoming very short. Waste reduction has not been part of our daily culture, and this has further shortened the life of landfill sites. Most new landfills are located further away from the waste generation zone resulting in higher disposal costs. As such, many countries are considering alternative methods of waste disposal, primarily focused on reducing the volume with bulk transport using transfer stations, thermal methods for large cities and composting for resource and nutrient recovery.

The solution to our waste disposal problems is not very easy, as the technical aspect has to justify waste management economy which always puts the cost as the main stumbling block. In this century, with the emerging green policies and high demand for renewable energy, the option to use municipal solid wastes or biomass as energy feedstock is becoming significant. With more than 17,000 tonnes/day of waste produced in the country, Malaysia has vast potential to utilise the wastes for wealth creation, converting it into valuable biofuel which will create significant savings both in landfill space and allowing energy to be recovered.

MUNICIPAL SOLID WASTES

Municipal solid waste (MSW) refers to garbage, refuse and other useless solid waste from residential, commercial, industrial, and community activities that the generator of the waste puts out for collection.

There are 8 varied categories representing municipal solid wastes:

1. Organic materials
   Food and kitchen wastes, vegetables and all putrescible items from domestic sources.

2. Paper:
   This category consists of all mixed papers, cardboards, card boxes, envelopes, parcels, newspapers, magazines and also old papers and newspapers.

3. Plastic
   PET (polyethylene terephthalate), HDPE (high density polyethylene), transparent or colored plastic films and transport packages are in this category.

4. Metals
   Aluminum, ferrous material and non ferrous metals used as containers or non-containers. Other metals from domestic sources such as tin, copper and zinc are common.

5. Glass
   This part is divided into 2 subcategories - containers (bottles) and non-container glass. It is also divided into white, brown and green glass due to different shape and color of the glass.

6. Wood
   Trees, treated and untreated woods, yard trimmings and wastes, wood panels and old furniture.

7. Rubber
   All rubber products from the household, clothes and consumer products containing rubber parts. This includes tyres.

8. Textile
   Fabric, clothing, ropes, linen, carpets, shoes, bags, mattresses and cotton rags.

Hazardous Waste

There are also some special waste categories, referred to as "Hazardous wastes" but which come from domestic sources. The examples are: Batteries, florescent lamps, solvents, paints, used oil or lubricants.

E-wastes

Electronic wastes are normally not included as municipal wastes, but they are found entering land disposal sites in growing quantities. These wastes contain electronic parts, metal such as gold, silver, lead, nickel, copper, cadmium and mercury. Electronic devices also contain glass and composite plastics. Most parts of e-wastes can be recycled.

Different sources of solid wastes have varied compositions. Table 1 shows the different types of solid wastes from different sources:

Table 1 Classification of Solid Wastes Based on Source

Source	Type of solid wastes
Residential	Food wastes, Paper, Cardboards, Plastic, Textile, leather, yard wastes, wood, glass, cans, metals, bulky items, consumer electronics, household hazardous materials
Commercial	Paper, Cardboards, Plastics, wood, food wastes, glass, metals, Hazardous wastes
Institution	As Above (commercial)
Construction and demolition	Wood, steel, concrete, dirt
Municipal service	Rubbish, street sweeping, Landscape and tree trimming, general wastes from parks,
Domestic Wastewater Treatment plant	Sludge, solid residue
Industrial	Industrial wastes, nonindustrial wastes, food wastes, rubbish, ash, demolition, hazardous wastes
Agricultural (field and farms)	Rubbish, food, hazardous wastes, agricultural wastes

GENERATION OF WASTES FROM ASIAN CITIES

Many factors affect waste generation, for instance GNP and urbanisation are two factors that contribute most to the amount of MSW generated. High income countries normally produce more wastes than others while developing cities will have a bigger organic fraction in their waste stream.

The amount and composition of waste generated is critical data in the formulation of new waste management plans and technologies. Accurate estimation of these variables is essential for the design of resource recovery and material cycle. Waste minimization will not be effectively carried out without having reliable waste composition data. Evaluation of impacts of certain types of waste and estimation of the life of landfills require sufficient waste composition data. [3]

It is expected that both waste quantity and composition vary widely from day to day and season to season. Considerable differences may be observed not only between countries but also between neighboring localities and between types of properties within the same town or cities.

The composition of wastes generated in selected Asian countries is given in Table 2. The percentages show that the organic portion accounts for more than 50% of the total waste except in the Philippines where its ratio is only 45%. The highest percentage of organic waste was recorded in Indonesia followed by China, 73.9% and 67.3% respectively. It is expected that a greater rural setting in a country would produce more organic waste such as kitchen waste and less of recyclable items such as paper, metals and plastics. The highest percentage for paper and plastics were observed in the Philippines where it was reported to be 16% and 17% respectively.

Table 2 Waste Composition in various Asian Countries

Component (% weight)	Malaysia	Philippines	China	Vietnam	Indonesia	Thailand	Cambodia
Kitchen Waste	56.3	45	67.3	51.9	73.9	55.4	50.4
Yard Waste	6.9	7	-	31.9	-	-	-
Plastics	13.1	16	13.5	3.1	7.9	16	15.5
Paper	8.2	17	8.8	2.7	10.2	12.9	10.6
Glass	1.5	3	5.2	0.5	1.8	4.2	1.8
Metal	2.4	5	0.7	0.9	2.0	2.8	0.4
Leather/ Rubber	0.4	1	-	1.3	0.6	1.6	0.03
Textile	1.3	4	-	1.6	1.6	2.6	1.7
Fines/ stone	0.4	2	-	6.1	-	-	7
Wood	1.8	-	-	-	1	4.5	10.2
Others	7.7		4.5		0.4	-	2.5
Total	100	100	100	100	100	100	100
Reference	2	5	6	7	8	9	10

As a result of rapid urbanization, solid waste generation in Asian countries in particular continues to increase. Figure 1 shows the urbanization pattern in selected developing Asian countries indicating the level of kitchen waste production in the capital cities of the respective countries. It appears that countries with lower urbanization such as Thailand, China, Indonesia and Vietnam generate large quantities of organic kitchen wastes. The level of urbanization of a country affects the composition of organic waste due to growing income and the new lifestyles of people living in urban areas. Greater consumerism tends to generate more packaging materials that have higher paper and plastic content.

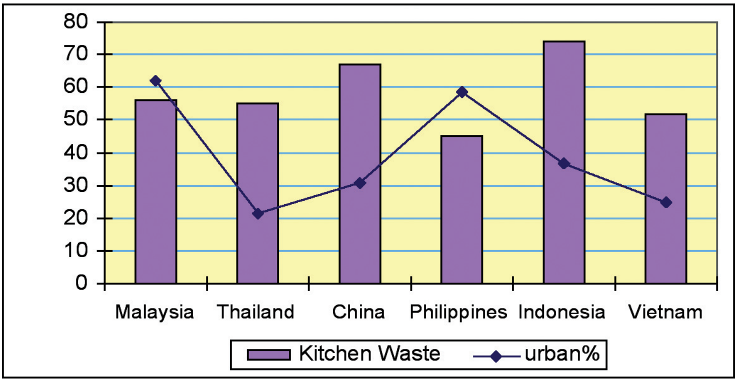


Figure 1 Urbanization in Developing Asian Cities and organic waste generation

The distribution of wastes according to Middle and High Income Countries in Asia are shown in Figure 2 and 3. The Middle Income Countries are Indonesia, Phillipines, Thailand and Malaysia, while the High Income Countries are Singapore, Korea, Hong Kong and Japan.[4]

Organic wastes are the main part of wastes in Middle Income Countries (including Malaysia). The proportion of organic wastes is 58% of total wastes. The share of paper, plastics, other wastes, metals and glass are 15%, 11%, 11%, 3% and 2% respectively (data in 1999).

As comparison, in 1999, solid waste composition in High Income Countries was 36% paper, 28% organic, 9% plastic, 8% metals, 7% glass and 12% other wastes. Obviously, there is a smaller organic fraction in wastes in Higher Income Countries.

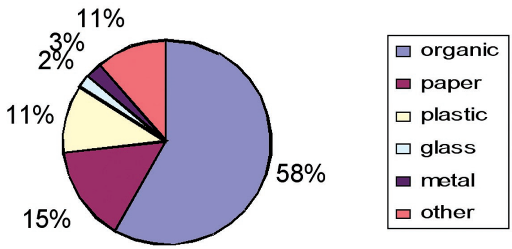


Figure 2 Composition of wastes in Asian Middle Income Countries (1999)

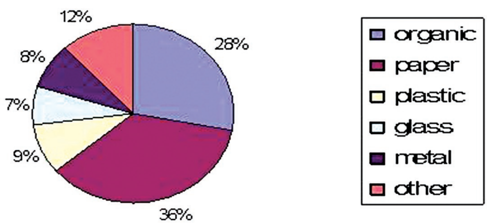


Figure 3 Composition of wastes in Asian High Income Countries (1999)

Increase in urbanization also affects the overall rate of solid waste generation in many countries. Critical issues related to collection, disposal method and dumping sites for MSW remain unsolved in many large cities. Due to the relatively wet climate in many parts of Asia, problems associated with the degrading organic portion in the waste poses the greatest challenge in terms of river and groundwater pollution.

In Kuala Lumpur, the rate of solid waste generation was 1.7 kg/ca/day (in 1999) and the city produced 2,500 tonnes/day.[2] In 2002, Kuala Lumpur waste generation was 3,000 tons/day and the total Malaysian MSW was 6 million tons per annum. The per capita generation rate for Malaysian cities ranges from 0.88 to 1.44 kg/day .[1]

In Manila, it was estimated that solid waste generation amounts to 5,245 tons per day or 14.5% of total nationwide generation. In urban areas, collection efficiency is 73% while it is only 40% in rural areas. Moreover, the implementation of ecological waste management programs helps to steadily increase recycling activities in major cities and municipalities [5]. It was reported that the latest figure for Manila's waste generation was 5,900 tons/day and the estimated total MSW generation was 10 million tons/year. The sources of MSW comprise 48% residential, 26% informal settlers and 26% commercial and industrial sources [6].

Solid waste is one of the major environmental problems in Thailand. In year 2003, solid waste generated was approximately 40,165 tons/day, which comprises 24% from Bangkok Metropolitan Administration (BMA), 31% from municipalities and 45% from rural areas. In 1993, the waste generation from Bangkok was 9,640 tons/day. It was estimated that the collection service covers 60 to 80% of the residences in the municipal area of Bangkok. [7]

In China, whose population was 1,286,975,468 in 2003, the average MSW generation was about 1.65kg/ca/day. There were 660 waste treatment sites/plants, which treat 60.2% of total MSW which is 118 million tons while the remaining 35% is dumped in the cities and suburbs.[8]

In Vietnam, 22,210 tons/day of waste is collected which represents a collection rate of about 60%. There are about 55 waste disposal sites in Vietnam. In Hanoi, the capital city, the waste generation was estimated to be 1,600 tons/day (87% collection). The average waste generated per person is 0.6 kg/day. [9]

For many developing cities in Asia, material recovery and recycling are normally not carried out by the local authorities or landfill operators. However, it is the activities of scavengers at landfill sites or unauthorized waste pickers which are contributing to reducing amounts of recyclable items such as paper, plastics, glass and metals in the wastes.

The prospect for material recovery and recycling in Asian cities appears to be high due to the growing increase in waste quantities as well as recyclable material in tandem with the country's move towards rapid development and industrialization. Figure 4 shows the composition of recyclable items found in the waste stream in selected countries. Items such as plastics, paper, glass and metals are potential candidates for recovery, reuse and recycling. Thailand and the Philippines produced more plastics than any other developing country (about 16%). Malaysia and China produced about 13% plastics while Indonesia and Vietnam recorded the lowest values (8% and 3% respectively). Paper items are also significant and they are collected and recycled in many countries - the composition found in waste is between 8 to 17%, except for Vietnam which generates only about 2.7% paper wastes.

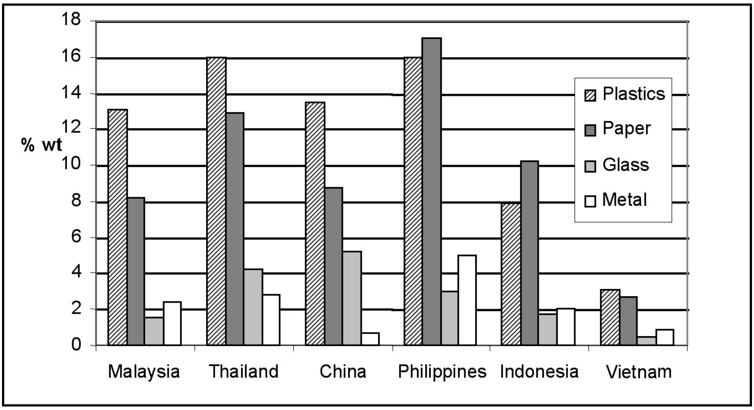


Figure 4 Composition of Recyclable Items in Waste

WASTE DISPOSAL TRENDS IN ASIAN COUNTRIES

Developing nations face various problems related to MSW. To carry out a systematic review of MSW problems and formulate a well-considered management plan, it is extremely important to understand the present MSW flow in the region. However, despite the importance of understanding MSW problems and formulating a suitable management plan, developing nations do not generally conduct MSW stream analysis; this is due to ignorance of the proper methods involved and funds required. Usually, international support agencies such as World Bank carry out studies on the amount of waste generation and its composition in developing countries. However, these studies are not carried out with the intention of determining the differences in urban MSW streams.[10] In the following, we have tried to compile the waste disposal trends from published data in Asian countries, namely China, South Korea and Taiwan, which exhibit dynamic changes in contrast to other developing Asian countries.

China

Landfilling is the dominant method of MSW disposal in China. According to an investigation of 138 cities in 2000,[11] landfilling accounts for about 96.9%, composting 1.3% and incineration 1.8%. This situation is not expected to change significantly in the near future, since separate collection is not practiced in most of the cities and installation and operation of incinerators are unaffordable for most of the Chinese cities. Currently, the simple landfill is considered a better option than doing nothing.[12]

Taiwan

A material flow study for MSW has been conducted for Taiwan, according to officially published data.[13] The ash amount is assumed, in average, to be 20% of the amount received by the incinerators. The minimization by incineration reaches about 43.6%, and the final landfill disposal is about 40.20% of the original amount. The improper disposal rate is 3.64% which includes non-sanitary landfill (2.76%) and other methods such as storage and dumping (0.88%). The recycling amount, which is diverted from incineration and landfill, is about 15.56%. However, the recycled or recovery amount that returns to the market is not clearly controlled as yet, which means that flow of waste and pollution transformation during the recycling processes is unknown.

In Taiwan, 36 large-scale MSW incinerators were planned to be built according to the incineration policy. At present, 19 plants are in operation, which incinerated 4.32 million tons (54.2%) of MSW and 1.28 million tons (2%) of general industrial waste in 2002. Plans for 6 plants were cancelled, 7 plants are under construction and 4 plants are in planning stage. Further, the EPA has announced intentions to follow the international trend of "Zero Waste" policy.

The goal for MSW minimization was 25% in 2007, 40% in 2011 and 70% by 2020.

South Korea

In South Korea, solid waste management system focusing on waste reduction recycling and proper treatment has been introduced since the 1988 Seoul Olympic Games. Consequently, Waste Management Law, Resource Concentration and Recycling Promotion Law, Law on the Waste Disposal Facilities Installation Promotion and Surrounding Area Support and the Law on Waste Movement and Disposal were established and revised in the early 1990s.[14] Accordingly, waste disposal does not solely depend on landfills as shown in Table 3 (domestic wastes).

Table 3 Disposal methods for domestic wastes in South Korea between 1996 and 2002[14]

Category %	1996	1997	1998	1999	2000	2001	2002
Landfill	68.3	63.9	56.2	51.6	47	43.3	41.6
Incineration	5.5	7.1	8.9	10.3	11.7	13.6	14.5
Recycling	26.2	29	34.9	38.1	41.3	43.1	43.9
Ocean dumping	-	-	2.2	3.0	3.1	3.1	3.6

LANDFILL METHOD

The most popular method of waste disposal in Malaysia is landfilling. In the past decade, many landfills were operated as Open Dumps, the easiest low cost method of landfilling which is very detrimental to the surrounding ecosystem. Later development of landfills consisted of Control Tipping where the sites were engineered to receive solid wastes and some compaction was carried out to allow for extra spaces. The Control Tipping suffered serious environmental problems as surface run-offs due to rain caused river pollution and the landfill generated bad odour which can reach few kilometers. Concern about landfill sites located close to residential areas and the pollution captured public attention when the source of drinking water, namely the nearby river, rapidly deteriorated and it becames very difficult to treat. The call for a better method of landfilling has been a hot topic in mainstream media and also research organizations, including Universities which are taking special interest in solid waste disposal and treatment research.

The main environmental impacts of landfill are:

- Leachate – pollutes surface and ground water
- Fire – generating smoke and haze
- Gas – release of methane and risk due to gas migration
- Landfill slope failure
- Bad odour
- Land subsidence and settlement
- Place for vector breeding

Some views on environmental issues related to landfills are presented in Figure 5 below.

Open Dump- worst | Open Dump-controlled

Landfill on Fire | Leachate Pollution

Leachate Polluting Nearby River | Landfill Near Residential Area

Figure 5 Environmental Issues of Landfill

The municipal solid waste landfill strategy today is a very much improved version. All aging and most problematic landfills have been ordered to close while several others are being upgraded into a better, modern system called Sanitary Landfill.

Malaysia adopted a classification system that describes landfill state of technology as follows.[19]

Level 1: Controlled Tipping.

Level 2: Sanitary Landfill with a Bund and Daily Soil Covering.

Level 3: Sanitary Landfill with Leachate Re-circulation System.

Level 4: Sanitary Landfill with Leachate Treatment System.

The latest assessment of landfill sites was carried out in 2002 and the results are summarised in Table 4.

There were 77 open dumps, 49 controlled tipping (Level 1) and only 35 for Levels 2, 3 and 4 landfill sites. The results also show that the largest numbers of open dumps were in Sarawak, followed by Johor, Sabah and Kelantan.

There are many problems associated with the use of landfills. The issues relate to environmental disorder, which usually brings about serious air pollution (from smoke and fire), bad odour, contamination of groundwater due to leachate and pollution of rivers.

Although landfills are not the best choice where pollution is concerned, they are still the preferred choice due to economic reasons. Modern landfills are designed to meet sanitary landfill requirements (Level 4) (Figure 6) and come complete with leachate collection and treatment systems (Figure 7).

Table 4 Number of Landfill Sites and Levels in Malaysia (up to March 2002)[16]

State	Number of Landfill Sites According to Types					Total Number
	Open Dumps	Level 1	Level 2	Level 3	Level 4	
Perlis	0	0	0	0	1	1
Kedah	3	2	3	0	1	9
Pulau Pinang	0	0	1	1	0	2
Perak	9	5	2	2	0	18
Selangor	0	7	1	1	2	11
Negeri Sembilan	6	3	1	1	0	10
Melaka	2	0	1	0	0	3
Johor	13	8	4	1	0	26
Pahang	5	3	2	3	1	14
Terengganu	2	4	1	0	1	8
Kelantan	10	1	1	0	0	12
Kuala Lumpur	0	0	0	1	0	1
Labuan	0	1	0	0	0	1
Sarawak	15	11	2	0	0	28
Sabah	12	4	0	1	0	17
						161

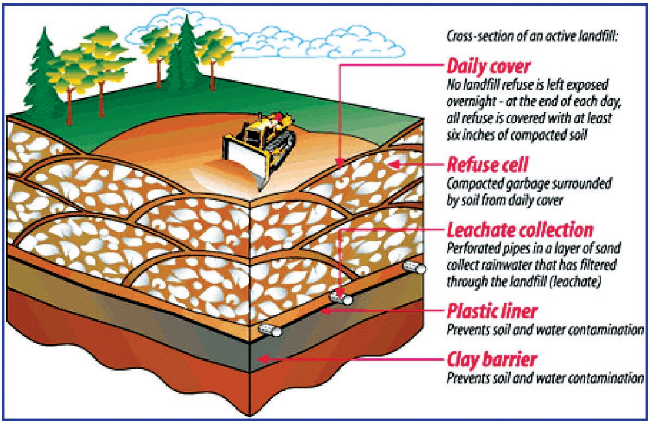


Figure 6 Schematic of Sanitary Landfill

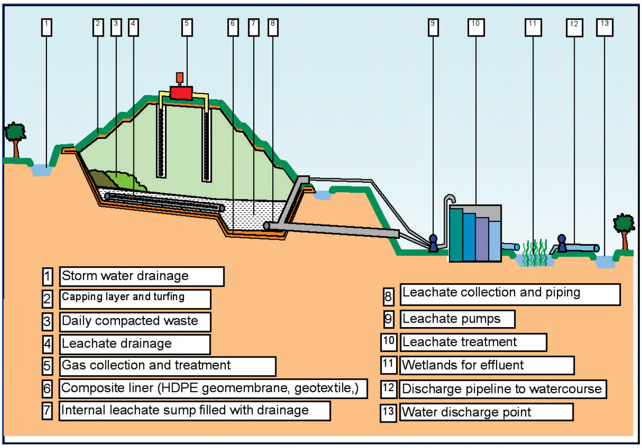


Figure 7 Leachate Collection and Treatment

ISSUES RELATED TO LANDFILLS IN MALAYSIA

The most sensitive and damaging impact of landfills is related to pollution of river systems. Several cases were reported that implicate leachate pollution as the cause of poor drinking water quality in Selangor.

Two case studies are reproduced here to demonstrate the nature of environmental issues and the impacts on the surrounding environment as a result of landfill practices in Malaysia. They provide lessons for future MSW management and can be used to derive alternative strategies in order to improve.

CASE STUDY 1 : EXPERIENCE OF A LANDFILL (AIR HITAM SANITARY LANDFILL) [1]

The Air Hitam Sanitary Landfill (AHSL) is located in the Petaling district around 9 km from the town of Seri Kembangan, Selangor and is under the jurisdiction of the Subang Jaya Municipal Council (MPSJ). The total area of the site is about 58.68 hectares and its actual waste-filling area, about 40.47 hectares. The landfill has been in operation since 1995 and so far more than 1.50 million tones of solid waste have been landfilled. The landfill was closed in 2006.

The Air Hitam Sanitary Landfill (AHSL) is the first privately operated, engineered, modern sanitary landfill in the country and can be categorised as a Class IV landfill site (the most advanced landfill) under the landfill classification system described above. The advanced features of the landfill include proper liner systems, gas ventilation systems and the most comprehensive leachate collection systems. AHSL started its operations in 1995 and the total amount of wastes deposited in the landfill as of April 1999 was about 1,251,037 tons with daily throughput of 1,500 tons.

Since the landfill site was well designed and systematically operated, all the leachate produced from the landfill was collected in the leachate collection pond for further treatment in the leachate treatment plant. The average amount of leachate discharged from the landfill was about 600m^3 per day. The amount of leachate produced from the landfill site fluctuates according to various factors particularly the amount of rainfall and the amount and composition of waste disposed.

The most distinctive feature of a landfill leachate is that the quantity and quality produced vary considerably. In literature, it is quite normal to see the range of chemical oxygen demand (COD) from 40 to 89,520 mg/l, biochemical oxygen demand (BOD_5) from 81 to 33,360 mg/l and Ammonia-nitrogen (NH_3-N) from 0 to 2000 mg/l. The AHSL had a similar problem i.e. extreme variations in leachate quality and quantity (Table 5). At the period of study, AHSL was treating the leachate using biological methods. The treatment process includes equalization pond, extended aeration lagoon where leachate is aerated following sequential batch reaction (SBR) method and sand filter bed. These are also the leachate treatment facilities suggested in the Technical guidelines on Sanitary Landfill in Malaysia. Leachate effluent was discharged into Sg. Rasau which flows along the landfill site.

The existing leachate treatment system was running with average removal efficiency of 72 to 80 percent for conventional pollutants, namely, BOD, COD, NH_3-N and TSS (Table 5).

However, the record shows that the leachate treatment plant could produce leachate effluent quality according to DOE's requirements of Standard B of Environmental Quality (Sewage and Industrial Effluents) Regulations, 1979 except for BOD, COD, NH_3-N, TSS and Fe.

Table 5 Leachate Characteristics of AHSL Landfill *(all units in mg/l except for pH; na- not available)*

Parameters	Raw Leachate		Leachate in Equalization pond		Leachate at discharge point	
	Range	Mean	Range	Mean	Range	Mean
PH	7.2-8.2	7.8	7.5-8.2	8.1	8.1-8.4	8.2
BOD_5	188-7838	2484.94	426-7988	2770.47	74-1514	575.9
COD	1211-39480	6367.96	1924-19463	7388.23	1412-3214	2038.3
TSS	16-1560	353.29	51-3760	485.28	140-1765	466.5
NH_3-N	1062-2989	2070.07	425-2655	1345.01	19-508	269.9
NO_2	0.02-63.80	8.05	0.03-30.60	5.67	0.3-824.36	251.2
NO_3	0.1-98.06	20.11	0.1-104.5	16.14	0.1-56.20	13.9
Alkalinity	1424-80614	16055.9	3495-141504	17626	1492-40736	6467.4
Hg	5.80	n.a	n.a	n.a	<0.001	n.a
Cd	<0.01-1.4	<0.014	n.a	n.a	<0.01-1.4	<0.014
Cr (hexa)	<0.01-0.35	<0.078	n.a	n.a	<0.01-0.35	<0.078
As	<0.01-0.07	<0.038	n.a	n.a	<0.01-0.07	<0.038
Pb	0.07-0.19	0.116	n.a	n.a	0.07-0.19	0.12
Cu	0.01-0.11	0.04	n.a	n.a	0.01-0.11	0.04
Mn	0.07-.42	0.164	n.a	n.a	0.07-.42	0.16
Ni	0.07-0.53	0.288	n.a	n.a	0.07-0.53	0.32
Sn	<0.01-0.08	0.024	n.a	n.a	<0.01-0.08	0.046
Zn	0.14-0.76	0.434	n.a	n.a	0.14-0.76	0.4
Fe	4.81-9.3	6.104	n.a	n.a	0.98-9.3	5.06
Ba	2.9	n.a	n.a	n.a	<0.01	n.a
Ag	<0.1	n.a	n.a	n.a	<0.02	n.a
Cl	88.3	n.a	n.a	n.a	36	n.a

Table 6 Leachate Characteristics at Air Hitam Sanitary Landfill Treatment Plant

Parameters in the leachate	Avg. Concentration in Raw Leachate	Avg. Concentration at the discharge point	Percent removal of the pollutants
pH	8.1	8.2	
BOD_5	2770	576	33.6-95.4 % (not complied)
COD	7388	2038	20-85.9 % (not complied)
TSS	485.27	532	3.86 % *(not complied)
NH_3-N	1345.01	270	(no requirement limit)
NO_2	5.67	251	(no requirement limit)
NO_3	16.14	13.9	(no requirement limit)
Alkalinity	15889.43	5544	(no requirement limit)
Cd	<0.014	0.02	Complied with Std.-B
Cr^{+6}	<0.078	<0.12	Complied with Std.-B
As	<0.038	<0.085	Complied with Std.-B
Pb	0.116	0.125	Complied with Std.-B
Cu	0.04	0.085	Complied with Std.-B
Mn	0.164	0.29	Complied with Std.-B
Ni	0.288	0.385	Complied with Std.-B
Sn	0.024	<0.04	Complied with Std.-B
Zn	0.434	0.85	Complied with Std.-B
Fe	6.10	5.6	Not complied
Ag	<0.10	na	(no requirement limit)
Free Cl	88.30	na	(no requirement limit)

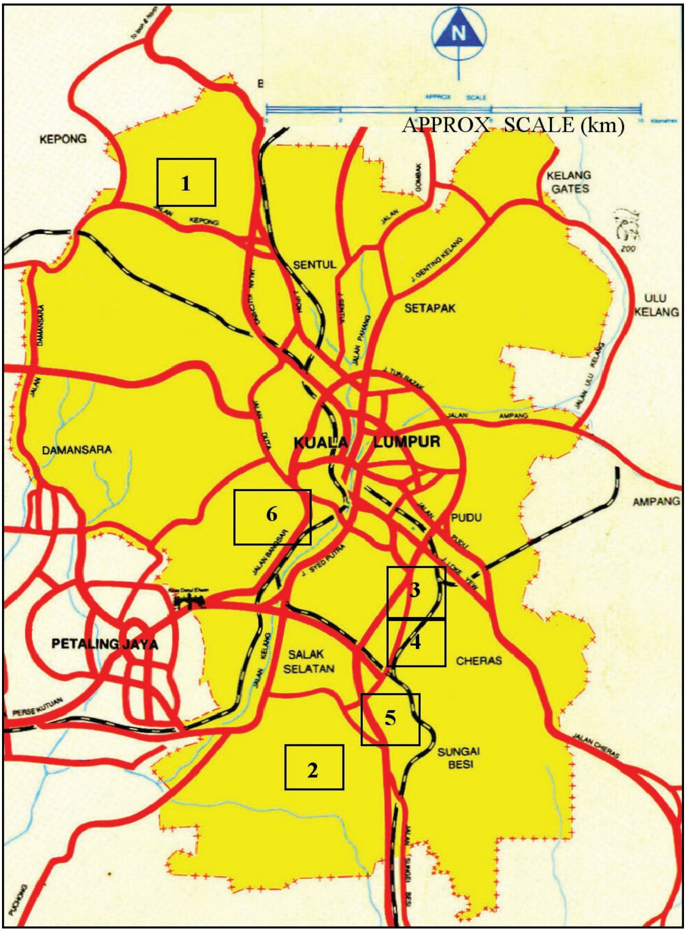
Note: All figures are in mg/l except for pH; na- not available, *- before installing sand filter bed, Compliance indicates compliance with DOE's Std.-B.

CASE STUDY 2 : EXPERIENCE OF CLOSED LANDFILL SITES IN KUALA LUMPUR

A detailed investigation and assessment of closed solid waste landfill sites in Kuala Lumpur was conducted in October 1997. Information gathered on the landfill sites in Kuala Lumpur indicates that these landfill sites can be categorised into three generations as follows:

- First Generation Landfill Sites:
  These are the landfill sites that were closed before 1975. These include Abdullah Hukum, Air Panas, Dewan Bandaraya Kuala Lumpur (DBKL) and Brickfields. Detailed information about these sites is almost negligible since the documents or files for each landfill site could not be traced.
- Second Generation Landfill Sites:
  There are two sites that operated between 1975 and 1990, i.e. Paka 1 and Sri Petaling Landfill sites.
- Third Generation Landfill Sites:
  These are the sites that were closed after 1990. Three landfill sites were identified to be in the third generation i.e. Jinjang Utara, Paka 2 and Sungei Besi.

The locations of the landfill sites are shown in Figure 8 below and the overall results of the study are summarised in Table 7, which highlights the fact that closed landfill sites still pose a threat in terms of air, water and soil contamination. The pollution from closed landfill sites could still pose health risks either directly (direct health risk) or indirectly (indirect health risk through consumption of contaminated groundwater near landfill sites).



Sites:

1-Jinjang Utara	4-Kg. Paka 2
2-Sri Petaling	5-Kg. Paka 1
3-Sungai Besi	6-Brickfields

Figure 8 Locations of Closed Landfill Sites in Kuala Lumpur

Table 7 Environmental Conditions of Closed Landfill Sites in Kuala Lumpur

Characteristics	Jinjang Utara (Lot No.10880)	Brickfields (Lot No.33518)	Sungei Besi (Lot No.104146)	Paka 1 (Lot No.751)	Paka 2 (Lot No.751)	Sri Petaling (Lot No.33518)
General Features	3rd Generation landfill site. 162 acres. Amount of wastes deposited ~ 6.6 million tonnes. Started operation: 1979. Year closed: 1996.	1st Generation landfill site. Other information not available.	3rd Generation landfill site. 34 acres. Amount of wastes deposited ~ 3.1 million tonnes. Started operation: 1989. Year closed: 1995.	2nd Generation landfill site. 32.2 acres. Amount of wastes deposited ~ 3.1 million tonnes. Started operation: 1989. Year closed: 1994.	2nd Generation landfill site. 25 acres. Amount of wastes deposited. Started operation: 1989. Year closed: 1994.	2nd Generation landfill site. 52 acres. Amount of wastes deposited: 7.1 million. Started operation: 1979. Year closed: 1991.
Gas Emissions	Major gases detected: CO_2 H_2S SO_2	Major gases detected: H_2S CH_4 SO_2	Major gases detected: CO_2 H_2S SO_2	Major gases detected: H_2S CO_2 CH_4	Major gases detected: H_2S CH_4 SO_2	Major gases detected: CO_2 H_2S

Characteristics	Jinjang Utara (Lot No.10880)	Brickfields (Lot No.33518)	Sungei Besi (Lot No.104146)	Paka 1 (Lot No.751)	Paka 2 (Lot No.751)	Sri Petaling (Lot No.33518)
Surface Water Quality	Critical pollutants: BOD, COD, NH3-N, PO_4. Class III of average water quality status	No water body found	No water body found.	Critical pollutants: BOD, COD, NH3-N, PO_4 Class IV of average water quality status	Critical pollutants: NH3-N, PO_4, TSS Class III of average water quality status	Critical pollutants: NH3-N, TSS Class III of average water quality status
Inorganic Chemical Characteristics of Pollutants in Soil Samples	Detection of cadmium (X), copper (X), silver (0), lead (X).	Detection of nickel (X), copper (X), cadmium (X), chromium (X) and lead (NC).	Detection of copper (X), silver (0), lead (X).	Detection of copper (X), silver (0), lead (X).	Detection of copper (X), silver (0), lead (NC).	Detection of cadmium (X), copper, silver (0), lead (X).

Characteristics	**Jinjang Utara (Lot No.10880)**	**Brickfields (Lot No.33518)**	**Sungei Besi (Lot No.104146)**	**Paka 1 (Lot No.751)**	**Paka 2 (Lot No.751)**	**Sri Petaling (Lot No.33518)**
Inorganic Chemical Characteristics of Pollutants in Groundwater Leachate and River Water Samples	Detection of nickel in groundwater (EX), copper in groundwater (EX), cadmium in groundwater (EXX), cadmium in river (EX), chromium in groundwater (X), lead in groundwater (X), arsenic in groundwater (EX)	Detection of cadmium in groundwater (EXX), lead and copper in groundwater (X), arsenic in groundwater (EXX)	Detection of nickel in groundwater (X)	Detection of chromium in groundwater (X), barium in groundwater (EXX), cadmium in groundwater (EXX)	Detection of nickel in groundwater (X), cadmium in groundwater (X), lead (X) mercury in river (EX)	Detection of nickel in groundwater (X), copper in groundwater (X)

Characteristics	Jinjang Utara (Lot No.10880)	Brickfields (Lot No.33518)	Sungei Besi (Lot No.104146)	Paka 1 (Lot No.751)	Paka 2 (Lot No.751)	Sri Petaling (Lot No.33518)
Organic Chemical Characteristics of Pollutants in Groundwater Leachate and River Water Samples	Detection of group 2 compounds, tetrachloro-methane (EX) Detection of group3 compounds, PCP (EX) Detection of group4 compounds, PAH (EX), DDE (EX)	Detection of group 1 compounds, ethyl benzene (X) Detection of group 6 compounds, chlorinated pesticides, the drins (aldrin, dieldrin, endrin) (EX), DDE (EX)	Detection of group 2 compounds, 1,2 dichloroethane (EX); Detection of group 3 compound (phenolic compounds), PCP (EX); Detection of group 5 compounds, 1,4-dichloro-methane (EX); Detection of group 6 compounds, chlorinated pesticides, the drins (aldrin, dieldrin, endrin) (EX), DDE (EX)	Detection of group 6 compounds, chlorinated pesticides, the drins (aldrin, dieldrin, endrin) (EX), DDE (EX)	Detection of group 5 compounds, 1,4-dichloro-methane (X) Detection of group 6 compounds, chlorinated pesticides, the drins (aldrin, dieldrin, endrin) (EX), DDE (EX)	Detection of group 1 compounds, ethyl benzene (X) Detection of group 2 compounds, 1,2

Notes: X – within limit or below intervention value and is considered uncontaminated,

0 – No background values and soil quality criteria.,

NC – Below the values that require cleaning up by the Dutch Standard,

EX – exceeded the Dutch “B” level but below Dutch “C” level or exceeded intervention value., EXX – exceeded Dutch “B” and Dutch “C” levels, i.e. require cleanup actions; exceeded the Malaysian raw water quality criteria and the Malaysian drinking water quality standard. Source: DOE (1999

CHANGING TREND IN WASTE MANAGEMENT

As the world moves towards a renewable economy, the potential for using waste as feedstock for biomass or biofuel is gaining greater attention. Many waste-to-wealth projects are being successfully implemented in advanced countries, including Japan. The principles are based on building an economy where the basic building blocks to produce energy is a renewable resource. Waste from municipalities is a large pool of renewable resource which can be utilized in a more beneficial manner. In this manner it will also achieve the sustainable development target to minimize carbon emission. We are looking to the day when a tonne of solid waste will be traded like a barrel of oil. At that time, everyone will be collecting and keeping their solid wastes for sale. Imagine how much better a place the world would be without waste dumps.

The changing trend from waste disposal to waste utilisation for energy is currently at the forefront of plans of many waste management authorities. Several options are available to convert MSW into biofuel, and these are presented in this section.

1. BIOMASS FOR ENERGY

As shown in Table 8, the share of global renewable energies will reach up to 22 % in 2050. Biomass, along with solar and wind will have the largest growth during this period

Table 8 Global Share of Renewable Energies

Source	2000 (%)	2020 (%)	2050 (%)
Wood, yard	10	8	5
Hydro	4	5	6
Biomass, solar, wind	2	4	11
Total share %	16	17	22

For Malaysia, the driving forces for adopting biomass or MSW as feedstock for renewable energy are:

- Climate Change – Global warming due to CO_2 emission from Fossil Fuels
- Earth Summit on Climate Change in Rio De Janeiro 1992
- Adoption of Agenda 2
- Alternative energy sources to replace fossil fuels
- Kyoto Protocol for Reduction of Green House Gases (GHG)
- Kyoto protocol ratified as International Law
- Less fossil fuel & more renewable energy
- Recent high crude oil priced reaching US140/barrel prompted the policy of greater use of renewable energy
- Malaysia adopted the 5th Fuel Policy for greater utilization of renewable energy: Target: 5% (500 MW) Renewable energy by 2010.
- To obtain Clean Development Mechanism (CDM) incentives - carbon trading using reduction in CO_2 emission.

Hence, it is anticipated that biomass utlisation as a resource will be widely considered for waste to energy projects to achieve the 5^{th} Fuel Policy as well as for protecting the environment. The oil palm sector is already leading in this case, but MSW conversion to energy projects are very much lacking.

2. TECHNOLOGY FOR CONVERSION OF WASTE INTO BIOFUEL

Conversion of waste into biofuel can be done in two ways:
(1) Thermo-chemical process
(2) Biological process.

Thermo-chemical processes consist of mass-fired combustion, gasification and pyrolysis. Biological processes include anaerobic digestion, fermenting and metabolic processes. In all above methods H_2 will be produced whether directly or indirectly. A schematic process diagram for biomass conversion into energy is as shown in Figure 9.

The gas produced, which is called biofuel, is a low or medium energy content gas. The energy content of natural gas is about 35 $MJ/N.m^3$. Synthetic gas which is produced by gasification contains only approximately 5 $MJ/N.m^3$.

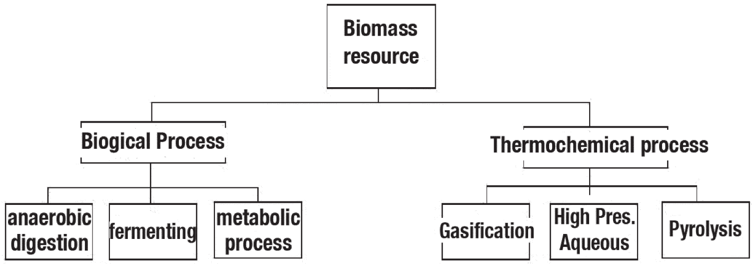


Figure 9 Biomass Conversion into Energy

Thermo-chemical Conversion

This method uses high temperatures to decompose wastes into a valuable product or biofuel. This category is divided into 3 sub-categories, namely, Combustion, Gasification and Pyrolysis.

Pyrolysis is operated in a non-reactive environment and gasification is done in a chemically reacted environment. Pyrolysis can be referred to as an incomplete gasification. In this pathway usually a mixture of gas, liquid and solid is produced. Characteristics of products can vary based on waste composition and type of materials.

Combustion

Combustion is a fast oxidation of materials to produce heat without generating any useful intermediates for further processes or consumption. In the MSW case, combustion mainly refers to incineration. Based on different materials used as feed, the furnace temperature may range from 800°C to 1200°C. Combustion suffers from many disadvantages, such as generation of toxic compounds in flue gas such as dioxin and furan. The heat generated from combustion is used to operate steam turbines for power generation.

The mass fired combustion is still a popular choice of converting MSW into power, especially for large cities. In the mass-fired combustion system, minimal processing is given to the solid waste before it is placed in a charging hopper of the system. The heat generated is utilised in heat exchangers whereby a steam boiler is used.

Figure 10 shows the illustration of a Stoker system Mass Fire Incinerator.

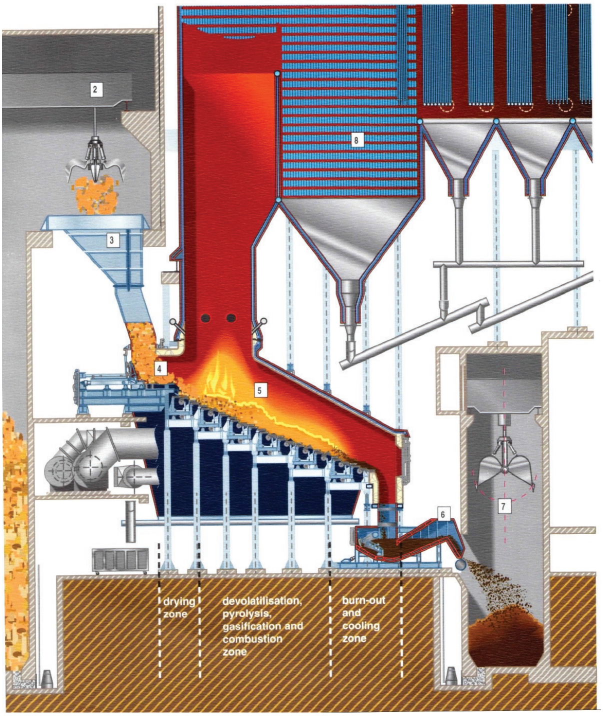


Figure 10 Mass Fire Combustion System (Incineration)

Gasification

Gasification is conversion of carbonaceous material to a gas fuel or a liquid fuel using partial oxidation or sub-stoichiometric air or oxygen during a high temperature process. The produced gas consists of CO, H_2, methane, some other light hydrocarbons, CO_2 and N_2 (if air is used in the process). Heat can be produced in an exothermic reaction (auto thermal reactions) or in an indirect method such as burners or heat exchangers. Depending on the waste stream used and process design, operation temperatures may vary from 700°C and above. Also, pressure in the reaction chamber might differ from atmospheric pressure to 5 atmospheres.

The main goal of gasification is to produce combustible gas, called synthetic gas (or syngas). However, liquid and ash may be produced as well. The biofuel produced in gasification can be used in internal and external engines (direct use), fuel cells and any heat or electricity generation equipment. Combustion of these biofuels generate the same final products which burning feedstock generates.

Nowadays, gasification of coal, petroleum and natural gas are common as commercially competitive ways to produce synthetic gas. In Europe and east Asia, gasification of biomass is used to produce heat and energy but only in small scale. In 2006, around 160 gasification facilities were built which generate about 37,000 MW of energy. [17]

The largest gasification system has been operating in USA since 1984. This facility converts coal to syngas. The largest facility for converting MSW is in Germany (FÜRTH plant) and in Japan, the most popular gasification systems are Fluidized Bed Gasifiers, where graded sand is used as the heating medium.

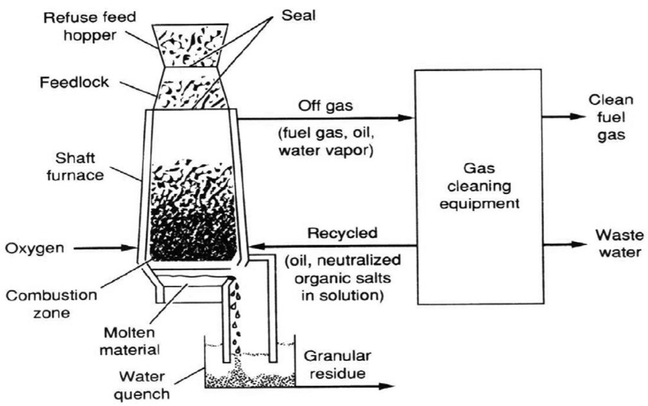


Figure 11 Typical Gasification Process for Municipal Solid Wastes

Pyrolysis

In the pyrolysis process, volatile components are vaporised at 600°C which produce hydrocarbon gases, hydrogen, carbon monoxide, carbon dioxide and water vapor. The pyrolysis temperature depends on system design and waste material feedstocks, but it can vary between 600°C to 1100°C [17]. Due to the high amount of volatile content found in biomass, 70 to 85 %, pyrolysis plays a large role in biomass gasification. However, ash and char (fixed carbon) are byproducts of pyrolysis which cannot be vaporised. By adding some oxygen, combustible parts can produce heat for repeated reactions.

In the pyrolysis process, the following reaction occurs :

$$\text{BIOMASS} + \text{ENERGY} \rightarrow CO + H_2 + CH_4$$

By adding oxygen in the reaction, supply of energy is not necessary and produced gas is diluted with CO_2 and Nitrogen (if air is used) as follows:

$$\text{BIOMASS} + O_2 \rightarrow CO + H_2 + CO_2 + \text{Energy}$$

To remove CO, water vapor is helpful to allow this reaction:

$$CO + H_2O \rightarrow CO_2 + H_2$$

Pyrolysis produces a liquid fuel called Bio-oil under an endothermic reaction:

$$\text{BIOMASS} + \text{ENERGY} \rightarrow \text{Bio-oil} + \text{Char} + \text{SynGas}$$

Results of some research shows that using suitable catalysts at 750 – 850 °C in two steps, may lead to:

$$\text{Bio- oil} + H_2O \rightarrow CO + H_2$$

Then:

$$CO + H_2O \rightarrow CO_2 + H_2$$

Figure 12 shows the pyrolysis process for conversion of waste into power.

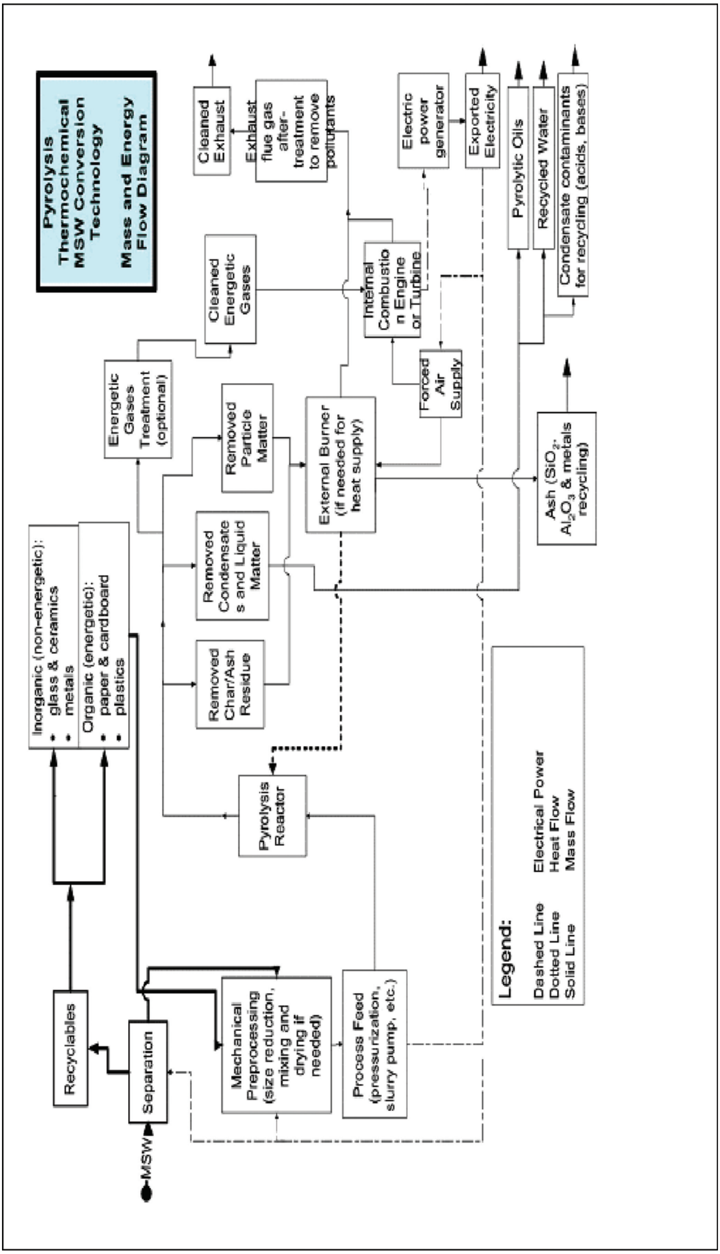


Figure 12 MSW Pyrolysis Process to Produce Electricity

Biological Process

The biological process that converts waste into biogas can be done using anaerobic digestion. The method is well known, just like a landfill produces biogas. Although slow in reaction, anaerobic fermentation or digestion with biogas recovery is most preferred when the landfill method of disposal is selected. However, the biogas quantities and gas composition may vary with age of landfill and amount of organic content in the waste.

Anaerobic Digestion

Anaerobic digestion is fermenting of materials – mainly organic matter in the waste stream. This pathway proceeds in absence of air or oxygen and produces gas fuel (called biogas) which consists of methane, carbon dioxide, moisture, hydrogen sulfide and some other trace gases.

This process operates at various temperatures from 10°C to 70°C. The proportion of carbon and nitrogen (C/N ratio) is important and methanogens should be controlled during digestion. Moisture content and nutrients also contribute to the overall production of biogas. In the anaerobic process, degradation of organics occur, producing volatile acetic acids which are later converted into methane and CO_2. The schematic process showing organic conversion into biogas can be seen in Fig. 13. Most anaerobic processes produce 50 - 60% methane and 40 - 50% CO_2.

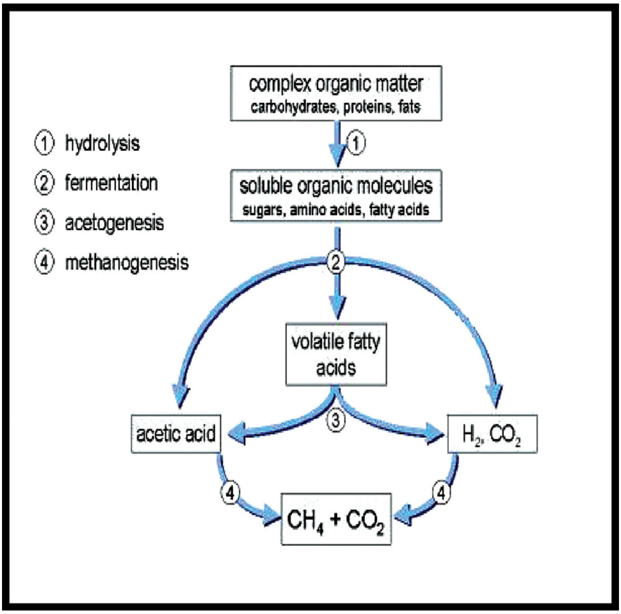


Figure 13 Anaerobic Digestion of MSW to produce Biogas

Fermentation

Fermentation is very similar to anaerobic digestion. This method mostly uses a conversion method of glucose to ethanol similar to beverage industries, fuel and chemical process fields. This pathway is an anaerobic process which is controlled by enzymes. Fermentation feedstock needs a preparation before process to break down heavy and complex molecules and fraction to lighter components such as sugar. After preparation (mainly Hydrolysis), microorganisms proceed with the fermentation. Ethanol and CO_2 are the first products. Producing more ethanol of around 12 % can stop fermentation. The ethanol should be removed from fermentation and be recovered as fuel, in this case bio-ethanol. Produced ethanol can also be converted to hydrogen in a further process.

RESEARCH ON SOLID WASTE AT UPM

There are many research activities related to municipal solid wastes carried out at UPM. Efforts are concentrated on two main research themes:

(1) MSW Treatment and Disposal
(2) MSW Treatment Technologies

While using incinerators for MSW is common, recent investigations focus on much more efficient processes such as microwave gasification and plasma conversion. Some recent lab studies on conversion of biomass sludge and oil palm empty fruit bunches into biofuel using microwave heating are at an advanced stage.

Microwave Gasification

Experiments are carried out using two different Microwave conversions in single mode and multi mode. The difference is the form of microwave radiation. The system consists of a source of microwave (magnetron), microwave guide, reactor, thermocouple, condenser and gas container.

The process is developed by placing MSW in a microwave reactor and allowing for removal of oxygen using He or Nitrogen. Studies are focused on investigating the biofuel quality, reaction time and formation of by-products. The final output will be the development of a novel microwave system capable of converting all MSW components into biofuel at much faster speed than conventional gasification or pyrolysis. The economics of using such technology will be evaluated against landfills, incinerators and composting.

Plasma Gasification

The most advanced research at UPM is the plasma pyrolysis using microwave. It is a thermochemical process with extremely high temperature, in absence of oxygen, to degrade wastes into simple molecules. The process is to release significant amounts of energy in the form of ultraviolet radiation which is produced by a recombination of ionized particles with the stripped electrons. The plasma environment is very reactive and the gas components in plasma pyrolysis are mainly methane and carbon monoxide. Further, in plasma gasification hydrogen also appears.

This method is very useful for the majority of waste – even toxic and hazardous wastes - without any need for separation of the wastes. The other advantage of plasma is the reduction of waste volume up to 99%. Moreover, this process does not result in any harmful residue. Furthermore, the emission level of plasma conversion is acceptable. Due to advantages of plasma, it is expected that this process will be used in various fields of wastes in the near future.

CONCLUSIONS

Municipal solid wastes continue to increase rapidly as population grows. The landfill method of disposing wastes in Malaysia has posed serious environmental problems, namely pollution of rivers and water bodies. New challenges faced by local authorities are related mainly to finding the best option for disposal of solid wastes. With the escalation of fuel prices and major pollution associated with landfills, MSW can be a potential resource for our renewable energy. There is strong justification to utilise solid waste as biofuel to produce electricity. Refinement of technology for conversion of waste material into biofuel is the next step which could change the landscape of today's waste management, from landfill disposal to resource recovery.

Biofuel economy has driven us to collect and use unwanted materials as valuable energy feedstock. With the emergence of new technologies for conversion of wastes into biofuel, the options are now becoming very clear. The Biofuel option can be the best strategy for MSW but our policies and implementation of plans should lend support toward achieving the sustainable development initiatives.

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BIOGRAPHY

Professor Dr Azni Idris was born in Kota Bharu, Kelantan just 12 days after independence in September 1957. He received his secondary education at Sultan Ismail College Kota Bharu, Kelantan. He continued to study at Sekolah Dato Abdul Razak in 1975 before going on to pursue his A-level education at Harrogate College in Yorkshire, United Kingdom. Prof Azni graduated from the University of Birmingham, UK (in Chemical Engineering) in 1980, and Leeds (MS Pollution Control) in 1983. He completed his PhD at University of Newcastle upon Tyne, UK in 1989 specialising in Environmental Engineering.

Prof Azni joined UPM as a tutor in 1980, and todate has been with UPM for more than 28 years. His academic expertise is in environmental engineering with special interest in waste management, water and wastewater treatment and toxic and hazardous waste management. He is very active in teaching and research and held the position as Director of Waste Technology Unit at the Faculty of Engineering from 1990 to 1999. From 1997 to 2005, Prof Azni held the position of Director, Technology Commercialisation Unit of University Business Centre (UBC), where he gained much experience in negotiations and the commercialization of UPM's research products. From 2006-2007, Prof Azni headed the Consultancy unit of UBC, taking on the post of Deputy Director, UBC.

Prof Azni leads many large research projects from the private sector such as UPM - Indah Water Konsortium Research on Sludge (RM2.3 million) in 1999 – 2008 and wastewater projects funded by the Ministry of Science, Technology and Environment of Malaysia (IRPA - total RM 3.6 million). Prof Azni has more than 26 years of experience in wastewater research and treatment processes, and he has been very active in many consultancy projects (waste management) providing technical expertise, advice in environmental design and treatment technology for many types of industrial wastewater. He is a very qualified and certified trainer for Wastewater treatment plant operators for the Government of Malaysia.

Prof Azni has several professional affiliations of international status in the area of waste management, including water and wastewater environment and has also earned local awards for his research work. For his great contributions to water and wastewater research, he was awarded the prestigious MWA Outstanding Research Award 2002. His contribution to the scientific community is extensive research related to industrial and municipal wastewater treatment and he is accepted as an expert in the field. In the international arena his involvements with JSPS of Japan, DANCED and UNESCO is very commendable as well.

In terms of publications, Prof Azni has more than 60 referred journals and about 100 publications in proceedings as well as 2 patents and 3 books. He has travelled to many countries and has secured more than 40 overseas travel grants to present papers at international conferences and seminars.

To his credit, Prof Azni holds a Malaysian Patent on Biofil Technology (MY127825A) – an innovative treatment process for organic wastewater using special Cosmo-balls plastic media. He filed his second patent on the use of biocoagulant for water treatment which scored a prestigious Gold medal at the INNOVA product exhibition in Brussels, in November 2008.

In training services, Prof Azni is a famous scholar and qualified trainer who has served many clients such as Environmental Institute of Malaysia (EiMAS), Department of Environment, Kuala Lumpur City Hall, Ministry of Housing and Local Government, Petronas

Bhd (National Oil Company), SIRIM, Golden Hope Bhd, Indah Water Konsortium Sdn Bhd, Institution of Engineers Malaysia and Saudi Arabia Engineering Council.

Prof Azni is currently the Head of Department of Chemical and Environmental Engineering at the Faculty of Engineering, with effect from January 2009.

ACKNOWLEDGEMENT

Prof Azni would like to take this opportunity to sincerely thank his colleagues and graduate students (past and present), for their contributions to his success. He is forever indebted to his family particularly his beloved wife, Rahana, his children Mujahid, Kamilah, Aqeelah, Atiyyah, Khaulah, Aishah, and Faseehah and to his son-in-law Daud and daughter-in-law, Mimi. Also to his grandchildren, Danish, Adam, and Dhamir. May Allah SWT bestow us with mercy, wisdom, good health, and unlimited Rahmah to meet the future challenges ahead. Not to forget, his indebtedness to his mother, Wan Mariam for caring and constantly making 'doa' for his success.

LIST OF INAUGURAL LECTURES

1. Prof. Dr. Sulaiman M. Yassin
   The Challenge to Communication Research in Extension
   22 July 1989

2. Prof. Ir. Abang Abdullah Abang Ali
   Indigenous Materials and Technology for Low Cost Housing
   30 August 1990

3. Prof. Dr. Abdul Rahman Abdul Razak
   Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops
   30 January 1993

4. Prof. Dr. Mohamed Suleiman
   Numerical Solution of Ordinary Differential Equations: A Historical Perspective
   11 December 1993

5. Prof. Dr. Mohd. Ariff Hussein
   Changing Roles of Agricultural Economics
   5 March 1994

6. Prof. Dr. Mohd. Ismail Ahmad
   Marketing Management: Prospects and Challenges for Agriculture
   6 April 1994

7. Prof. Dr. Mohamed Mahyuddin Mohd. Dahan
   The Changing Demand for Livestock Products
   20 April 1994

8. Prof. Dr. Ruth Kiew
   Plant Taxonomy, Biodiversity and Conservation
   11 May 1994

9. Prof. Ir. Dr. Mohd. Zohadie Bardaie
   Engineering Technological Developments Propelling Agriculture into the 21st Century
   28 May 1994

10. Prof. Dr. Shamsuddin Jusop
    Rock, Mineral and Soil
    18 June 1994

Waste Management, What is the Choice: Land Disposal or Biofuel?

11. Prof. Dr. Abdul Salam Abdullah
Natural Toxicants Affecting Animal Health and Production
29 June 1994

12. Prof. Dr. Mohd. Yusof Hussein
Pest Control: A Challenge in Applied Ecology
9 July 1994

13. Prof. Dr. Kapt. Mohd. Ibrahim Haji Mohamed
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