Penerbit Akademia Baru

Journal of Advanced Review on Scientific Research
ISSN (online): 2289-7887 | Vol. 7, No.1. Pages 1-13, 2015

The Potential of Biodrying as Pre-treatment for Municipal Solid Waste in Malaysia

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Abstract – *The condition of Municipal Solid Waste (MSW) in Malaysia, which contains excessive moisture complicate the segregation process of recycling and making the use of such technology as solid waste burning unsuitable and harmful. In addition, not much MSW pre-treatment is carried out in Malaysia to reduce the moisture content. Although Malaysia's first waste-to-energy plant has proven to be relatively efficient in generate renewable energy, the technology is still facing problems due to the natural features of MSW in Malaysia that is too wet. Biodrying is an economic and environmental friendly method because the main principle utilises internal energy by organic waste decomposition. In this study, the potential of biodrying to reduce excessive moisture content for MSW in Malaysia was investigated using experimental laboratory scale biodrying reactor. The results showed the final moisture content for biodrying process was 24.1% reduced from the initial moisture content of 66.5% while the calorific value increased from 1210 Kcal/kg to 3420 Kcal/kg.*

Keywords: Municipal solid waste, excessive moisture, renewable energy, biodrying**.**

1.0 INTRODUCTION

In developing countries such as Malaysia, solid waste generation increases from year to year without effective and systematic management. Even though Malaysia is being a developing country, the increasing rate of solid waste generation is not in conjunction with the efficiency of solid waste treatment, expertise, manpower, land scarcity as well as facilities [1]. Statistics from the Department of National Solid Waste Management (NSWMD) has reported that the average solid waste collection for every state in Malaysia during 2011, 2012 and 2013, are respectively 27,575.40 tonnes/day, 28,565.32 tonnes/day and 29,590.82 tonnes/day. According to the statistics, the expected waste generation of 31,000 tonnes in 2020 is impossible if the solid waste problem has yet to be addressed. Solid waste generation in Malaysia is increasing due to various factors including urbanization and population increases at a rate of 2.4% per year, or about 600,000 per year since 1994 [2]. The average rate of solid waste generation in Malaysia is 0.5 - 0.8 kg/capita/day in rural areas, and 1.7 kg/capita/day in urban areas [3].

Solid waste composition is considered as fundamental issue to almost all aspects of solid waste management. The biggest obstacles are the nature of our garbage in terms of the waste condition which is too wet and mixed. The 9th Malaysia Plan estimated that about 45% of future waste will be made up of food waste, 24% of plastic, 7% of paper, and 6% of iron and glass. The percentage shows that the Malaysian solid waste contains a high concentration of food waste and organic waste, consequently has high moisture content and bulk density above 200 kg/m^3 as reported in Table 1. It is because of the variety types of foods that depend upon the variability of races and cultures in Malaysia. Moreover, local tradition foods in Malaysia originate from the cream of coconut, and curry could be classified as wet food. In Selangor, the highest percentage of MSW consisted of putrescible waste of approximately 46%, followed by plastic and paper at 15% and 14%, respectively [4]. The results showed that organic waste is a major problem in the Malaysian solid waste management. Organic waste which is also known as putrescible waste can be converted into value added products such as compost, biogas and others. Recently, the most common and widely practiced nature's way of recycling organic matter is composting. However, few operators are willing to recycle organic waste and it usually ends up in the landfills.

Table 1: Characteristics of Kuala Lumpur MSW

Proximate analysis (wet)	Weight (%)
Moisture content	55.01
Volatile matter content	31.36
Fixed carbon content	4.37
Ash content	9.26
Other parameters	
Bulk density (kg/m3)	240
Net calorific value (Kcal/kg)	2180

Source: [3]

Biological drying also known as biodrying is part of composting which has a good potential as a pre-treatment of MSW especially with high concentration of organic waste. Biodrying is the process by which biodegradable waste is rapidly heated through the initial stages of composting to remove moisture from a waste stream. In biodrying processes, the drying rates are augmented by biological heat in addition to forced aeration. On the other hand, the process of biodrying could be a good solution for MSW management, allowing the production of refused derived fuel (RDF). This method is very practical, especially to solve the excessive moisture in solid waste. Though this technique does not resolve the entire problems of solid waste, it can divert a large amount of waste, especially organic waste from landfill disposal. This paper discusses the background of solid waste treatment in Malaysia and the potential of biodrying MSW to be practiced in Malaysia.

2.0 SOLID WASTE MANAGEMENT IN MALAYSIA

The management of MSW in Malaysia is under the jurisdiction of Ministry of Housing and Local Government (MHLG). Prior to this, MSW management in Malaysia is under the local authority, as stipulated in Section 72 of the Local Government Act 1976. Under this act, the local authority is expected to provide, directly or through contract, public cleansing services, collection and waste disposal in a sanitary manner. However, local authorities have been facing a lot of problems in terms of collection and transportation. On average, they spent 50% of the local authority's operating budget to MSW and more than 50% is spent on the collection of waste. Thus, the government has set up a new solid waste management structure, under MHLG, which known as National Solid Waste Management Department

ISSN (online): 2289-7887 | Vol. 7, No.1. Pages 1-13, 2015

(NSWMD) as the regulatory body and the Solid Waste and Public Cleansing Management Corporation to conduct the operations. National Strategic Plan for Solid Waste Management in Malaysia (NSP 2005) proposed an integrated MSW management that practices waste management hierarchy that emphasizes the concept of reduction, reuse and recycling (3R), followed by the treatment and the final choice of methods of disposal as described in Figure 1. However, to date, waste disposal into landfill remains the country's leading practices.

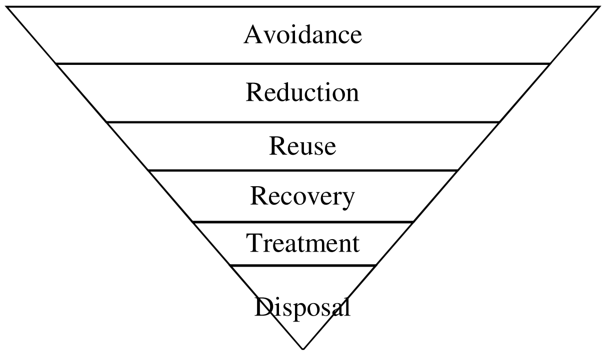

Figure 1: Solid Waste Method Hierarchy
Source: [5]

2.1 Concept of Reduction, Reuse and Recycle (3R)

Initiative to encourage public to apply 3R as their practice is very beneficial for reducing waste disposal mainly to landfill. Globally, recycling has been widely accepted as a sustainable solid waste management method because of its potential to reduce disposal costs and waste transport costs and to prolong the life spans of landfill sites [6, 7, 8]. This approach requires an enormous commitment from the community or society to be involved in efforts to manage solid waste.

Definition of reduction is to reduce and avoid buying unnecessary items. Meanwhile, reuse means the use of the product, including diversifying the use of the material in retaining its original form or as an alternative, with or without changes, while recycling means collecting and sorting waste for the purpose of producing products. The Government has set a target to increase the recycling rate by 1% each year by setting a target to achieve a recycling rate of 22% by 2020 [9]. However, this target seems difficult to achieve, because at present, the recycling rate in Malaysia is only at the level of 5 to 6% as shown in Table 2. This achievement is very low compared to other developed countries like Germany 60%, Belgium 71%, Austria 67% and the Netherlands 66% [10]. One of the reasons of low recycling rate is because of lacks of response and participation from public [11].

On the other hand, they also stated that lack of market for recyclables, diminished public confidence due to poor collection services, lack of public awareness and promotion program, lack of participation by stakeholders, lack of local authority personnel dedicated to the program and lack of policy and master plan focusing on recycling also contribute to recycling limitations in Malaysia.

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ISSN (online): 2289-7887 | Vol. 7, No.1. Pages 1-13, 2015

Table 2: Percentage of Solid Waste Methods in Malaysia

Treatment	Rate Percentage (%)		
	2002	2006	2020 (Target)
Recycling	5	5.5	22
Composting	0	1	8
Incineration	0	0	16.8
Inert Landfill	0	3.2	9.1
Sanitary Landfill	5	30.9	44.1
Other disposal sites	90	59.4	0
Total	100	100	100

Source: [12]

2.2 Composting

Composting is an alternative to organic waste treatment. This treatment method are highly encouraged to be practiced by people because it can be done on a small scale, namely in the backyard or on a large scale based. Composting is the biological decomposition of organic substrates involving mesophilic and thermophilic bacteria to produce a stable end product to be stored and applied to land without adverse effect to the environment [13]. The final product also contains 1% of trace elements such as nitrogen, phosphorus and potassium that can improve soil fertility and productivity. There are various ways and methods practiced among ordinary composting pile or open methods, mechanical, vermicomposting and thermophilic. In the present, the Takakura method is being promoted in Malaysia by the NSWMD to the public, which is very simple and user friendly technique.

2.3 Incinerator

In Malaysia, there are five small thermal treatment plants or incinerators which located at Pulau Pangkor, Pulau Langkawi, Cameron Highlands, Pulau Tioman, and Labuan with a capacity of 15 tonnes per day to 100 tonnes per day [14]. Unfortunately, these high technology methods are still facing a problem especially with city dwellers across Malaysia. The reason of high moisture content of materials such as organic waste make Malaysian waste is not suitable to be incinerated and require the input of other fuels. Among the issues raised is the release of health-threatening gases such as furans and dioxins into the air. Thermal treatment plants have to comply with the conditions set by the Department of the Environment (DOE), for example the rate of emissions of dioxins and furans in the 0.1 ng TEQ/Nm^3. Although the method of incineration is considered high-tech, the appropriateness of this technology with the characteristics of the composition of solid waste in Malaysia should be considered. Compared to Japan, incinerator is considered to be one outstanding disposal method in their country because of the citizen has already done the separation of waste at source. Due to incinerator conditions in Malaysia nowadays, existing smaller incinerators do not seem to provide positive results and some are not even in operation upon completion as this technology poses financial burden with its escalating cost of operations [13].

2.4 Disposal

The method of disposal of solid waste at the landfill site is dominant in Malaysia [15]. Statistics have shown in Table 3, which only 11 sanitary landfills were designed and equipped with the engineering operations according to the standards set. The basic principle of operation of a sanitary landfill is the preparation of the liner to prevent groundwater contamination, leachate management systems and methane gas collection system and cap to prevent any seepage of solid waste buried [16]. Nevertheless, the heavy dependence on landfill is not an effective option. This is because the waste conditions are too wet which can contaminate the surrounding circumstances such as river and soil. In addition, studies have shown that the emission of methane gas happens when organic waste is left to decay anaerobically in landfill [17]. On the other hand, the capacity of the landfill is very limited. Nowadays, landfilling is facing more difficulties due to most landfills are approaching its threshold or already exceeded its maximum capacity. New landfill construction sites become more challenging because of land scarcity and the proliferation of land values [2]. On the other hand, the value of land in the vicinity of the landfill will also go down.

Table 3: Sanitary Landfill Site in Malaysia

State	Sanitary Landfill	Inert Landfill
Johor	2	0
Kedah	0	0
Kelantan	0	0
Melaka	0	0
Negeri Sembilan	0	0
Pahang	0	0
Perak	0	0
Perlis	0	0
Pulau Pinang	0	1
Selangor	3	2
Terengganu	0	0
Sabah	0	0
Sarawak	3	0
Total	8	3

Source: [14]

3.0 METHODOLOGY

3.1 Biodrying mechanism

The basic principle of MSW biodrying is the reduction of the moisture content using internal thermal energy of the microorganism's activities to decompose organic waste [18, 19] and assisted by ventilation. The rate of evaporation process could be very fast with the appropriate combination of ventilation and natural decomposition activities that occurred in biodrying reactor [20]. In biodrying process, the biodegradable waste materials will decompose mainly to produce heat or energy, carbon dioxide (CO_2) and water (H_2O). This heat assisted by air is used to evaporate the excess moisture and is also able to enhance the calorific values in MSW. Equation 1 shows the aerobic digestion reaction during biodrying process.

Organic waste + Oxygen (O_2) → Carbon dioxide (CO_2) + Water (H_2O) + Energy (Heat) (1)

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3.2 Biodrying Reactor Set-ups

The biodrying reactor (Figure 2) was located within the Faculty of Engineering and Built Environment at Universiti Kebangsaan Malaysia (UKM). To prevent heat loss during the process of biodrying, the reactor was made of high-density polyethylene (HDPE) for the outer wall and polyurethane (PU) for the inner wall. The reactor capacity was 50 L, with an external dimension of 600 mm length x 400 mm width x 360 mm height and an internal dimension of 540 mm length x 345 mm width x 275 mm height. The reactor was equipped with a 2 horse power air compressor (Brand: Swan, Model: SVP-202) for ventilation. The air compressor was connected to a digital mechanical timer and valve to control the air interval time of ventilation in the system. An air flow regulator was connected to the reactor to control the air pressure entering the biodrying system. A tubing system was used to connect each component of the biodrying reactor, using 12 mm diameter tubing for external connections and 8 mm diameter tubing for internal connections. The waste sample in the biodrying system was covered by a non-woven, thermally resistant, polypropylene geotextile, which had a specially designed surface treatment that allows rain to flow easily off of the outer surface. At the same time, moisture inside the reactor could evaporate easily through the porous structure of the geotextile cover. The reactor was equipped with a temperature sensor connected to a data logger, which allows the collection and monitoring of temperature data inside the biodrying system.

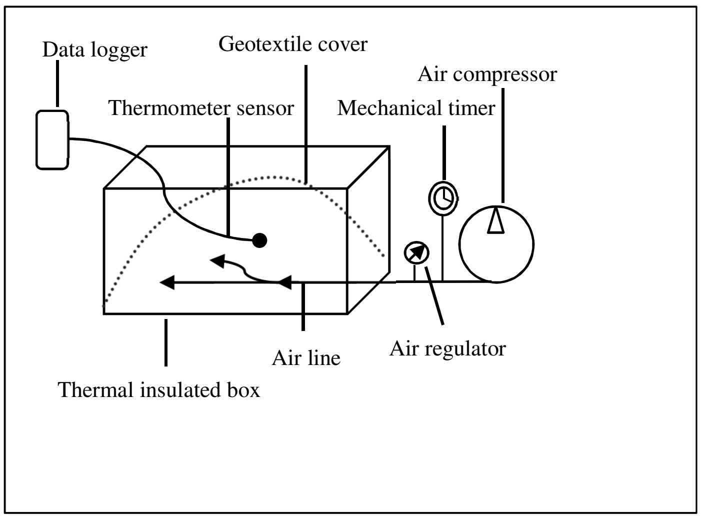

Figure 2: Schematic of the laboratory scale biodrying reactor.

3.3 Waste Sampling Procedure

The Synthetic Municipal Solid Waste (SMSW) was prepared to simulate an average weight percentage composition of MSW components generated in Malaysia referring a source from the NSWMD (2013). Table 4 shows the composition of SMSW prepared for this study. The preparation of SMSW involved weighing the required amount of waste components and mixing activities until the moisture distribution appeared.

Table 4: Composition of SMSW

Components	% by Weight	Material Used
Food Waste	47	Food waste taken from cafeteria (cut into 6-mm pieces)
Paper	15	Shredded paper taken from Administration Office (less than 3 mm wide and 25 mm long)
Plastic	14	Plastic (less than 3 mm wide and 15 mm long)
*Glass	3	N/A
*Metal	4	N/A
Textile	3	Textile (less than 3 mm wide and 10 mm long)
Wood	4	Wood shavings from pet shop
*Leather/Rubber	1	N/A
Other	9	Diapers (less than 3 mm wide and 10 mm long)

* Glass, metal and leather/rubber were not included because these are non-combustible materials and can be recycled.

3.4 Experimental setup

The laboratory scale experimental research was performed using two biodrying reactors which reactor A as the control process and reactor B for the biodrying process. Two sets of SMSW samples, weighing approximately 12 kg each, were fed into both rectors. Reactor B was supported with air ventilation system while reactor A was not supported by air ventilation. The ventilation times for reactor B was 15 min ventilation and 3 hours without ventilation, respectively for 14 days. Wood shavings were used as a bulking agent to provide structural support and maintain air spaces within the waste matrix. All experiments consisted of one replication. The waste was carefully turned manually every 2 days to avoid the formation of a moisture gradient. While turning the waste in each container, approximately 100 grams of waste was collected at three different levels and transferred to the UKM laboratory for proximate analysis of moisture content and calorific value. This avoided the interruption of microbiological processes during biodrying. Estimation of the waste moisture content (wet basis) followed the American Society for Testing and Materials (ASTM 2003) E989–88 [21]. The calorific value of MSW was determined by calculation referred to Pearson's The Chemical Analysis of Foods 6th Edition [22]. Measurement of moisture content was conducted in triplicate for each sample, and the standard deviation among samples was less than 5%. The moisture content was recorded on alternate days from day 1 and followed on days 3, 5, 7, 9, and 11, with the final measurement on day 14. However, calorific value was measured on the first and final day. The control and biodrying process was conducted over a period of 14 days under the typical conditions for the biodrying process [23]. Temperature was monitored daily by a thermometer with sensor probes located in the middle of the waste core.

4.0 RESULTS AND DISCUSSION

4.1 Moisture Content and Calorific Value

Moisture content and calorific value are the most important parameters to determine the biodrying performance. Moisture was removed by the combination of biological and physical factors in biodrying process i.e. by the heat produced an exothermal microbial reactions and the air flow rate [24]. Initial moisture content of solid waste in biodrying should be between 55% and 70% [25]. Low level of moisture content below than 40% caused slower microorganism’s activity and interfered with their metabolic processes. This indicated that

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the low moisture content of the MSW limited partially the biological activity [26]. While when the initial moisture content is too high, the heat derived from the biodegradation is not enough to make water evaporates [19]. Based on the high moisture content in the Malaysian MSW, the process of biodrying is ideal for being practiced as pre-treatment prior to disposal or recycling to convert into energy.

Table 5 presents the results of the laboratory analysis of the moisture content and calorific value for two different constructional solutions. Based on Table 5, both reactors had a decreasing in moisture content, reactor A and B, respectively from 67.00% to 43.9% and 66.5% to 24.1%. However, the results of the calorific value showed a gradual increasing for reactor A and B, respectively from 960 Kcal/kg to 2010 Kcal/kg and 1210 Kcal/kg to 3420 Kcal/kg. The relationship between moisture content parameter and day also showed a significant correlation at a level 0.01 based on Pearson Correlation analysis. Figure 3 shows the reduction of moisture content percentage of reactor A and B. From the results, both reactors show the percentage of moisture content reduction less than 50%. However, the final result for reactor B shows the acceptance percentage for RDF or energy purposes which is less than 25 % while end result for reactor A did not achieve RDF requirements. This condition proves that air ventilation or aeration which is included as operational parameter in biodrying system is very important for biodrying assistance. The optimal ventilation time can assist the microorganisms' activities in the reactor thus can be the cost-effective biodrying process.

Table 5: Moisture Content and Calorific Value between Reactor A and B

Reactor	Moisture Content, %		Calorific Value, Kcal/kg	
	Initial	Final	Initial	Final
A	67.0	43.9	960	2010
B	66.5	24.1	1210	3420

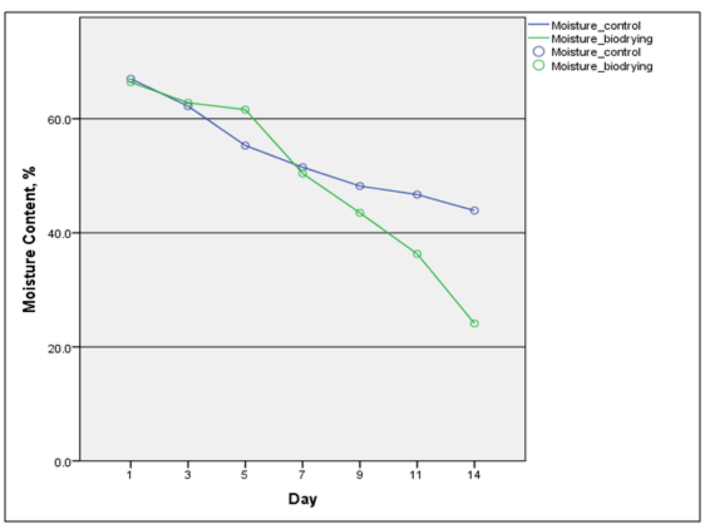

Figure 3: Moisture Content Reduction for Reactor A and Reactor B

Calorific value of MSW in Malaysia is in the range of 1,200 Kcal/kg to 1400 Kcal/kg while the calorific value of the fuel derivatives is increased to 4,000 Kcal/kg to 4,500 Kcal/kg [3]. Roughly 28% to 32% of the original MSW ends up as fuel. This fuel is suitable for controlled

Journal of Advanced Review on Scientific Research
ISSN (online): 2289-7887 | Vol. 7, No.1. Pages 1-13, 2015

combustion rather than MSW incineration, thus allowing strict pollution control. Based on the results of calorific values of this study, it shows that reactor A as well as reactor B still has not achieved the calorific values for the use of RDF. These low results for calorific value were due to the remaining moisture content in biodrying process. The prolonged of biodegradation process in biodrying process may affect the calorific value and the degree of stability of the final product especially for RDF [20]. Because of this study was a preliminary for biodrying process in Malaysia, other operational factors should be taken into consideration to improve the efficiency of the final results for moisture content and calorific value.

5.0 THE IMPORTANCE OF BIODRYING

5.1 Renewable Resource

Utilisation of fossil fuels has been practiced in the past years as a source of energy. However, this utilisation produce greenhouse gases such as CO_2, SO_2, NO_x and other pollutants which increase global warming and acid rain [27]. In addition, fossil fuel resources are depleting while the consumption is increasing. This environmental effects and fossil depletion necessitates the effort in the invention of alternative source of clean and renewable energy. Renewable energy sources such as hydroelectric energy, solar energy, geothermal energy and biomass can replace even a small portion of the power provided by fossil fuel. Solid waste is categorized as one of the sources of biomass energy because of the organic materials from plants and animals. In addition, solid waste also contains biomass such as paper, cardboard, food scraps, grass, leaves, wood and leather products, and other non-biomass materials such as plastics and flammable synthetic materials made from petroleum.

The increasing amount of MSW generation in Malaysia allows biodrying method to be implemented as a solution specifically to produce renewable energy. The process has been shown to produce fuel with decreasing moisture content and increasing energy content [28]. Biodrying is able to dry biomass while maintaining and increasing the calorific energy [20]. Drying of solid waste using natural metabolic concept for the production of heat from the decomposition of microorganisms and assisted by ventilation can produce fuel, as one of the alternative energy sources among industrialized areas such as cement manufacturing plants [29]. Although Malaysia has a waste-to-energy plant, which converted MSW into RDF for the use in an integrated steam power plant, the plant still had problems due to wet waste resulting in technical and operating damaged. The Malaysian government is targeting that at least six percent of the electricity generated will be obtained through the renewable energy by 2015.

5.2 Environmental Impact

Biodrying is a method that can reduce the amount of solid waste dumped to the landfill. As mentioned before, landfill which is not particularly sanitary contributes numerous negative impacts on the environment. Landfilling method is an anaerobic process. It produces landfill gases that consist of CO_2, CH_4 H_2S, NH_3, and other traces of gas that contribute to global warming. Hence, the biodrying method also can be applied as a pre-treatment prior to disposal to landfill. Furthermore, transition to biodrying method also can extend the landfill life span and latter reduce the production of greenhouse gases such as methane and carbon dioxide as the process of decomposition of organic matter have been reduced at landfill.

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In general, biodrying treatment plant provides a method of ensuring the sustainability of the environment by reducing the amount of wastes dumping to landfill, increasing the amount of solid waste that can be recycled and recovering energy from residual wastes by producing RDF [30]. Moreover, the decline of the high moisture content after biodrying process also allows the thermal treatment such as incineration without requiring a lot of fuel and is able to minimize the release of toxic gases such as dioxins and furans.

5.3 Economical aspect

One of the most important factors in choosing a drying method is cost. Biodrying can benefit many parties, particularly the government, by reducing the costs of operation and maintenance. The biodrying process utilises internal energy to dry the waste, unlike conventional drying processes, which require expensive equipment and are costly to operate. Although conventional drying has the advantage of drying waste more rapidly, from an economic and environmental perspective, biodrying is a more suitable method. Economic data regarding biodrying plant and rotary drum dryer system are shown in Table 6, for a capacity of 20,000 tonne per year.

Table 6: Capital and Operating Cost between Biodrying and Rotary Drum Dryer

System / Item	Biodrying		Rotary drum dryer	
	Investment (USD)	Operating and Maintenance (USD)	Investment (USD)	Installation and Maintenance (USD)
Plant	2,400,000	115,000		
Dryer			5,200,000	10,000,000
Furnace			350,000	500,000
Total			5,500,000	10,500,000
Grand Total	2,515,000		16,000,000	

Source: [30,31]

It is clear from Table 6, biodrying investment for solid waste drying method is more economical compared to rotary drum dryer system. The different cost between both drying methods was approximately 8 times. In terms of high moisture content in Malaysia's solid waste, the usage of rotary drum dryer seems not appropriate. It is because high water content in solid waste causes the temperature of the combustion chamber low, since most of the heat energy is used for evaporation. This condition creates incomplete reaction of combustion.

6.0 CONCLUSION

Biodrying is still at an infant stage in Malaysia. Previously, the advanced and engineered technology include sanitary landfill at Bukit Tagar, Selangor, RDF plant at Semenyih, Selangor and small incinerators at five islands in Malaysia as mentioned above, still facing inadequacy to treat or resolve approximately 30,000 tonne solid waste. Due to public opposition in incineration, biodrying method is very suitable either to replace these expensive technologies or made as pre-treatment method prior to process in thermal treatment plant or to dispose into landfill. Technology adopted from developed countries such as biodrying is not necessarily effective for our country but should be modified according to local conditions. In this study, biodrying technology has been shown as an intense potential to be developed in

Malaysia. Besides providing energy cost savings, biodrying is intended for drying of solid waste so that it can be used as a biodried product or recycled into fuel derivatives which have a high calorific value.

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