

Alternative Approach toward Waste Treatment: Biodrying for Solid Waste in Malaysia

Nurul'Ain Ab Jalil, and Hassan Basri

Abstract—This paper reviews the objectives, methods and results of previous studies on biodrying of solid waste in several countries. Biodrying of solid waste is a novel technology in developing countries such as in Malaysia where high moisture content in organic waste makes the segregation process for recycling purposes complicated and diminishes the calorific value for the use of fuel source. In addition, the high moisture content also encourages the breeding of vectors and disease-bearing animals. From the laboratory results, the average moisture content of organic waste, paper, plastics and metals are 58.17%, 37.93%, 29.79% and 1.03% respectively for UKM campus. Biodrying of solid waste is a simple method of waste treatment as well as a cost-efficient technology to dry the solid waste. The process depends on temperature monitoring and air flow control along with the natural biodegradable process of organic waste. This review shows that the biodrying of solid waste method has high potential in treatment and recycling of solid waste, be useful for biodrying study and implementation in Malaysia.

Keywords—Biodrying of solid waste, Organic waste, Fuel source.

I. INTRODUCTION

CURRENTLY, municipal solid waste management is a major concern to our society especially amongst local authorities, academicians and members of environmental associations. A lot of initiatives have been done and extensive campaigns on solid waste management have been conducted to give awareness to the community on how to manage as well as minimize their waste. Solid waste can be defined as the useless and unwanted products in the solid state derived from the activities of and discarded by society. Thus, with population growth, municipal solid waste generation also increases, which makes the solid waste scenario become crucial. Despite the population factor, the other major impacts are rapid urbanization and industrialization.

Agamuthu et al. [1], in Peninsular Malaysia, the daily generation of waste escalated from 13,000 tonnes in 1996 to 19,100 tonnes in 2006. It shows that the amount of municipal solid waste in West Malaysia rose significantly over the past 10 years. Approximately 75% of this is collected and disposed off in 130 landfills and dumps [1]. An estimated 20% is burned or dumped into rivers or at illegal sites, while 5% is

recycled [2]. At present, the main option of waste disposal has been landfilling, although many alternatives have been explored. As we know, landfilling is not an environmentally friendly approach to our lives since the release of leachate from landfills into water resources could affect humans and aquatic life. Moreover, the main source of manmade methane gas is from landfills. Emission of methane gas happens when organic waste is left to decay anaerobically in landfills. Methane gas is a threat to human health and is a documented factor in global warming. Solely depending on the disposal method to solve the solid waste problem is not a permanent cure. Thus, other treatments or techniques should be studied and introduced to moderate the solid waste problem other than waste minimization approaches.

According to the statistics, 48% of recyclable waste generated in Malaysia is from organic and food waste. 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, with the balance made up of other materials. The percentage shows that organic waste which contains food waste still contributes the highest amount in waste composition. Organic waste which is also known as putrescible waste and wet type of waste can be converted into value added products such as compost, biogas and others. The most common and widely practiced nature's way of recycling organic matter is composting. It is a process where biodegradable organic matter is broken down by microorganisms in the presence of oxygen. The product of this process is compost, which benefits the environment as a natural fertilizer to enhance plant growth and improve soil condition. Temperature, moisture content, nutrient content, pH, particle size, and oxygen supply are among the factors that will determine the quality of the compost [3]. Therefore, it is necessary to maintain proper environmental conditions for microbial life.

Biological drying also known as biodrying, is part of composting. Biodrying is the process by which biodegradable waste is rapidly heated through initial stages of composting to remove moisture from a waste stream and hence reduce its overall weight. In the biodrying processes, the drying rates are augmented by biological heat in addition to forced aeration. The process of biodrying could be a good solution for municipal solid waste management, allowing the production of refused derived fuel (RDF). The latest European Union policy on waste management recommends recycling, energy recovery and waste treatment before landfilling [4]. Therefore, the biological processes such as biodrying represent a good initiative as pre-treatment before landfilling. Although, these techniques do not resolve the entire problems of solid waste, it

Nurul'Ain Ab Jalil is with the Department of Civil and Structural Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Darul Ehsan, Malaysia. (Phone: +60038921450; email: nurulain@ukm.my)

Hassan Basri is with the Department of Civil and Structural Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Darul Ehsan, Malaysia. (email: hassanbinbasri@gmail.com)

can divert a large amount of waste, especially organic waste, from landfill disposal.

The biodrying system is a relatively new technology especially in developing countries. Hence, not a lot of research have been reported and are ongoing on this area. However, research related to biodrying methods of solid waste has been studied since 90's. Research on biodrying of solid waste in UKM is still in its initial stage. This paper reports the objectives, methods and results of previous studies on biodrying of solid waste in several other universities.

II. LITERATURE REVIEW

A. Biodrying vs. Biostabilisation and Composting

Biostabilization and biodrying are innovative technologies to solve problem related to organic waste. The distinction between both treatments is after biostabilization, the final product can be used for agriculture purposes or the biostabilized material can be stored safely in a landfill [5]-[6]. Whereas, in the case of biodrying, the refuse can be used as a source of energy such as RDF [7]. Both processes involve aeration of the mass of waste. Nevertheless, biostabilization aims for the highest conversion of organic carbon, while for biodrying the aims for the exploitation of the exothermic reactions for the evaporation of the moisture content in the waste, with the lowest conversion of organic carbon [8]. In biodrying, the main drying mechanism is convective evaporation, using heat from the aerobic biodegradation of waste components and facilitated by mechanically supported air flow [9].

On the other hand, biodrying differ from composting in terms of the objectives of each process [9]. Composting produces humus like compost that can be beneficially and safely applied to land and agriculture. Composting is also used to stabilise the biodegradable organic material of municipal solid waste prior to landfill disposal, minimising leachate and landfill gas formation. In contrast, the biodrying system aims to pre-treat waste at the lowest possible residence time in order to produce a high quality RDF. This is achieved by increasing the effective energy content by maximising removal of moisture present in the waste and preserving most of the gross calorific value of the organic chemical compounds through minimal biodegradation [7].

B. The Influence of Biomass Temperature and Air Flow

Among the early studies carried out about biodrying of solid waste was done by researchers from University of Trent, Italy and Technical University of Bucharest, Romania. They have combined their expertise, studied on the influence of temperature and air flow in the process of biodrying. They have created a biodrying reactor of solid waste known as adiabatic composting reactor i.e a process of chemical reactions which do not involve any admission or release heat. The biodrying process that occurs in an adiabatic reactor is based on the influence of heat which is mechanically flowing from the aerator to the steel diffuser.

The study on the influence of biomass temperature on biodrying process has been studied by Adani et al. [7]. Three different biomass temperatures were tested which are 70°C, 60°C and 45°C. The results showed that a temperature of 60°C

gave good results for low moisture content, high energy content and good biological stability to the end product. Hence, the product of biodrying could be used for RDF or stored with minimum pollution impact. The study was continued by Sugni et al. [14] to investigate the influence of air flow in the biodrying process. The data from Adani et al. [7] also evidenced that if the conditions do not consider pile turning and the air flow is always from one direction, temperature gradients arise within the biomass, resulting in a lack of homogeneity in the moisture and energy content of the final product. In addition, the results indicated that appropriate management of the processing parameters; air flow rate and biomass temperatures could achieve biomass drying in very short times of about 8 to 9 days.

The study done by Sugni et al. [14] involved varying the air flow direction through biodrying process to obtain more homogeneous final product. Three trials were carried out using 45°C set-point temperature. Trials A and B considered static conditions of the mass and one way air-flow occurred in the adiabatic reactor while trial C utilized a periodic inversion of the air flow through the biomass. In the case of trials A and B, the material came from the same sample used in Adani et al. [7] work. From the results, the moisture loss from this experiment compared to the previous study was about 200g kg⁻¹. The comparison of results between trial A performed in the Adani et al.'s work and Sugni et al.'s work presented in Table I.

TABLE I
 COMPARISON BETWEEN TRIAL A PERFORMED BY ADANI ET AL. (2002) AND SUGNI ET AL. (2005).

| | Adani et al. | Sugni et al. |
|---|--------------|--------------|
| Water losses (g kg ⁻¹ initial content) | 667 | 535 |
| Energy content _{ECstart} (kJ kg w.w ⁻¹) | 10,856 | 8,330 |
| Energy content _{ECend} (kJ kg w.w ⁻¹) | 14,056 | 9,824 |

C. Combined Hydrolytic-Aerobic Biodrying Technology

The research on biodrying of waste has been expanded by researchers from the University of Tongji, Shanghai, China. Zhang et al. [15] introduced a combined hydrolytic-aerobic technology in the process of biodrying of solid waste to remove water from solid waste as well as reviewing the air flow rates and duration of the hydrolysis process. The hydrolysis process was applied to this biodrying system because they found the ratio of water in organic materials was too high, in which case the heat generated from the decomposition process can not lead to the evaporation process to be occur completely. Thus, more water is constrained by the membrane or cell wall of the organic matter and can only be removed when the membrane is broken. Hence, the hydrolysis process can help this condition by breaking the membranes. The study was conducted on samples of 32 kg of solid waste which took about 16 days while the turning process was done every 2 days. From the results, the water content in the solid waste decreased from 72% to 50.5% at the end of the study. Based on the calculations, the water loss efficiency was 78.5%. During the hydrolysis process, the high temperature

recorded with high frequency ventilation in ventilation frequency of 10 times a day for 4 and 6 days.

D. Designs of Autothermal Drying

Research in the field of biodrying of solid waste continued the development of a drying tunnel reactor with an automatic control for the processing parameters to produce bioenergy. This study was an effort of a group of researchers from the University of Lodz, Poland after finding that studies by Adani et al. and Sugni et al. did not describe in detail the design of their biodrying reactor. Zawadzka et al. [16] developed three designs for the biodrying reactor that can accommodate high moisture content known as the drying tunnel.

The first reactor design was built vertically with a total capacity of 120dm³. The reactor was constructed with polyurethane foam as thermal insulation, inlet and outlet for air flows and biofilter for odour. Air flow was supplied 15 minutes/hour and the process duration takes about 11 days. For the second design, the reactor was built horizontally with a total capacity similar to the first reactor. In contrast with the first reactor, the second reactor can be rotated by the engine and the metal bar which placed on the walls of the reactor was used to mix the waste. For the second reactor, the process duration was 8 days.

The third reactor was designed and developed in more detail in which the total capacity was larger at 240dm³. It was built horizontally with additional transverse heating equipment that was placed at inlet air flow. Biodrying process in this reactor was assisted by air flow and four temperature sensors were placed separately. The process duration was 10 days. From the results, the third reactor showed a high percentage of water reduction of 50% while with the first and second reactors, respectively recorded 30% and 20%. In addition, third reactor also showed a higher temperature during the process of 53°C compared with the first and second reactors of 33°C and 40°C respectively.

E. Energy Recovery Optimization and Landfilling Minimization

A recent approach based on a one-stream Biological Mechanical Treatment (BMT) was done by Rada et al. [8] involving the materials valorization and energy recovery in municipal solid waste management. The researchers presented some aspects related to the scientific introduction to the biodrying process in Romania and the use of RDF in an industrial district, with a consequent minimization of landfilling volumes. The final material was RDF and after a refining stage can be sent to coal fired power stations or to cement kilns for partially substituting coal and pet-coke [10]. Based on the results by Rada et al., more than 25% of mass was lost during the biodrying process. This indirectly helps in reducing transportation costs. The lower heating value (LHV) had also increased from 25% of municipal solid waste to 33% for biodried materials and 49% for RDF.

III. METHODOLOGY

The location of this preliminary study is located at the main campus of Universiti Kebangsaan Malaysia (UKM), Bandar Baru Bangi, Malaysia. Solid waste collected will be studied in

order to know the total quantity and composition of solid wastes collected in the campus. The waste collected will be sorted into organic, paper, plastic, metal and others and weighed to determine the percentage of each waste component. This method follows the accepted standards for statistical sampling as outlined in the ATSM Standard Test method [11]. The amount of moisture content in each waste composition will be determined. The results of moisture content experiment which was done on 10 samples of solid waste are shown in Fig. 1. The results indicate the possibility of implementing of biological drying system as an alternative to landfill disposal. It showed that organic waste had the highest composition of moisture content which constituted about 58.17% compared to other waste components (Fig. 2).

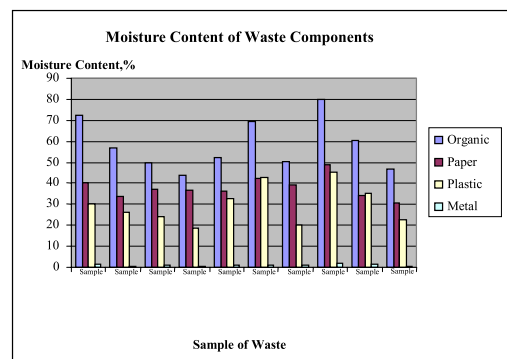


Fig. 1 Moisture Content According to Components of Waste

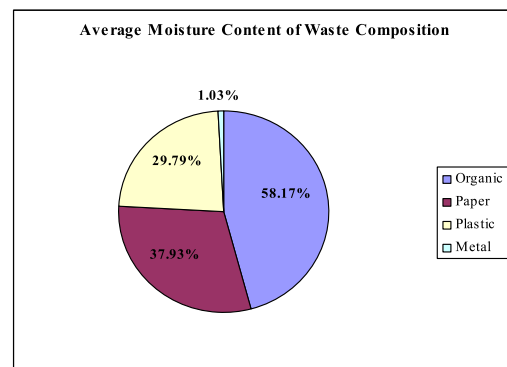


Fig. 2 Average moisture content of waste composition

The experimental set-up consists of the first prototype of the biodrying reactor which will be located at Faculty Science and Technology Laboratory in UKM. The biodrying reactor will use a combination of physical and biochemical processes. The main drying mechanism is evaporation using heat from the aerobic biodegradation of organic waste components and facilitated by the mechanically supported compressed air flow. The reactor design includes a fiberglass container with tiny holes on top of its cover complete with an aeration system. On the biochemical side, aerobic biodegradation of readily decomposable organic matter will occur. On the physical side, air flow rate and temperatures will be controlled. Fig.3 represents the schematic diagram for the biodrying reactor.

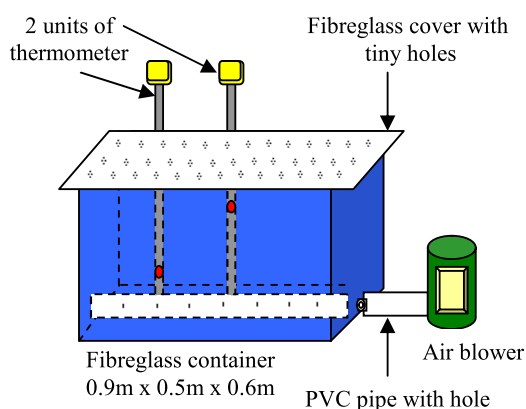


Fig. 3 Schematic diagram for biodrying reactor prototype

The process parameters for temperature and air flow rate will be examined daily to obtain the optimum correlations for fast biodrying. The temperature will be measured by a thermometer with the sensor probes located at the top, middle and inlet of air flow. The air flow meter will be adjusted manually from 10 psi to 70 psi. After the biodrying process is complete, the samples will be collected from different depths to determine moisture content, calorific value and total organic carbon. At the laboratory, determinations of the moisture content and total organic carbon will be carried out according to the ASTM Standard Test Method for Total Moisture in a Refuse-Derived Fuel Laboratory Sample [12]. The calorific value of the MSW was determined by using Bomb Calorimeter, which is also in accordance with ASTM Standard Test Method for Gross Calorific Value of Refuse-Derived Fuel [13].

IV. CONCLUSION

Research on biodrying in UKM is still at preliminary stage. This paper reviewed previous studies on biodrying of solid waste in Italy, Romania, Poland and China. Most of the research on biodrying of solid waste focused on the elimination of moisture content and the influence of operational parameters such as temperature and air flow. This is because, apart from the main process of aerobic decomposition of waste, the optimal condition for the temperature and air flow rate could make the biodrying more efficient and practical. On the other hand, the reactor design from previous studies was more suited to laboratory scale operation and not similar to the industrial scale practice. Therefore, further study will be conducted to design and construct a reactor more similar to industry practice.

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