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Design of Biodrying Mswreactor

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Abstract:- Bio-drying (biological drying) is one alternative of bioconversion in solid waste treatment plant that commonly known as Mechanical Biological Treatment, MBT. The main purpose of bio-drying process MSW is to reduce the water content in the municipal solid waste by reducing the mass and increasing the calorific value of the waste. The rate of evaporation of water content in the effluent depends on the characteristics of the waste. The characteristics of municipal solid waste in each country is different, therefore should not have the same biodrying process characteristics. Objectives of this study are to determine the characteristics of the process and to design a bio-drying equipment for household waste in Indonesia, which has a high water content. Preliminary studies were carried out to determine optimum conditions for air at 25 liters per minute and processing period of 7 days by using a dynamic model of reactor (in alternating every 3 days). This data were used to design a bio-drying with a capacity of 50 kg of municipal solid waste. According to dimensional calculation, it was determined that the optimum reactor was having a length and a width of 0.7 m2 and a height of 1.1 m

Keywords:- MSW, Biodrying, Mechanical Biological Treatment, Dynamic Reactor, Calorific Value.

I. INTRODUCTION

Mostly, large cities in Indonesia have a huge problem with their household waste.It is one of the problem that quite difficult to handle. The most effective treatment is to pile upthe waste in landfill and burning the trash. Household waste consists of flammable materials such as paper, plastics, food, etc. (Abu-Qudais, 2000; Hwang et al., 2008; Malkow, 2004; Rigamonti et al., 2009)[1,2,34]. Organic waste requires a long time to dry naturally,around 30-50 days. Application of naturally biological drying bins is not effective and efficient when it is used in large scale due to size limitations of the land andhigh energy costs for waste incineration (Navaee-Ardeh, 2010).

One of the effective methods used for drying biologicaly waste is bio-drying. Bio-drying of household waste (Bio-drying of Municipal Solid Waste) is a biological drying process which is followed by aeration to control the operating conditions of the reactor. This method has been successfully carried out in developed countries such as in America, Europe, and China since 15 years ago (Rotter et alp., 2004; Velis et al., 2009). In the developed countries,municipal waste is used for source of energy (WTE). After sorted, dried, and crushed, it is then burned together with fuel oil in the furnace to generate steam, becausethis waste has a high-value heat, with the Lower Heating Value (LHV) is about 3 to 6.7 MJ / kg (Zhang et al., 2010).

The commonmethod formunicipal waste dryingthat applied in developed countries is bio-drying. Biologically,it uses microbial activity to reduce the water content in the garbage, therefore it increases the calorific value of the garbage. The heat source for the drying process inbio-drying derived from the exothermic reaction of biological degradation trash. The drying process of bio-drying can increase the speedof evaporation of waste watercompared to natural dryingbecausethe degradation process condition is well controlled.

Municipal solid waste (MSW) in many developing countries, such as Indonesia, has different characteristics compared to the developed countries. It has a higher water content.An analysis shows that water content in the trash is 60-75% w/w. The variation of water content causes the characteristic bio-drying process (dwell time and speed of evaporation) is different. Designing bio-drying equipment required data of processcharacteristic for determination appropriate dimensions to the desired capacity. It is necessary to study the characteristics of bio-drying process waste in order to obtain data of residence time and drying speed. This study is carried out to design bio-drying equipment based on research data of characteristic process.

II. METHODS AND DESIGN

Initially. the research was to determine residence time of trash and drying speed before calculating the design. The data wasused tocalculate dimensions of the equipment with the capacity 50 kg of waste. Flow diagram of research methods and design can be seen in Figure1.

Research Stage

The stages of research includes the preparation, calculation of MSW waste composition, calculation of MSW water content, calculation for the average density of MSW garbage, and reactor design of bio-drying for laboratory-scale research. The data collection and analysis of each stage can be described as follows:

1. Preparation of MSWWaste

- Sample trash was taken in landfills
- Organic and inorganic waste were separated
- Organic waste was weighed as much as 50 kg

2. Calculation of MSW waste composition

- Organic waste was grouped based of its fibre
- The mass from each group of garbage were weighed
- The composition of garbage was calculated in masspercentage

3. The calculation of the water content of MSW garbage

- Waste samplewas taken from each group based on its fibre
- Mass from each sample of waste was weighed.
- Sample of garbage was put in an oven
- Sampleof garbage was cooled in the desiccator
- The mass of each sample was weighed based on each group
- The above steps were repeated until the weight is constant
- The percentage of waste water content was calculated in mass percentage

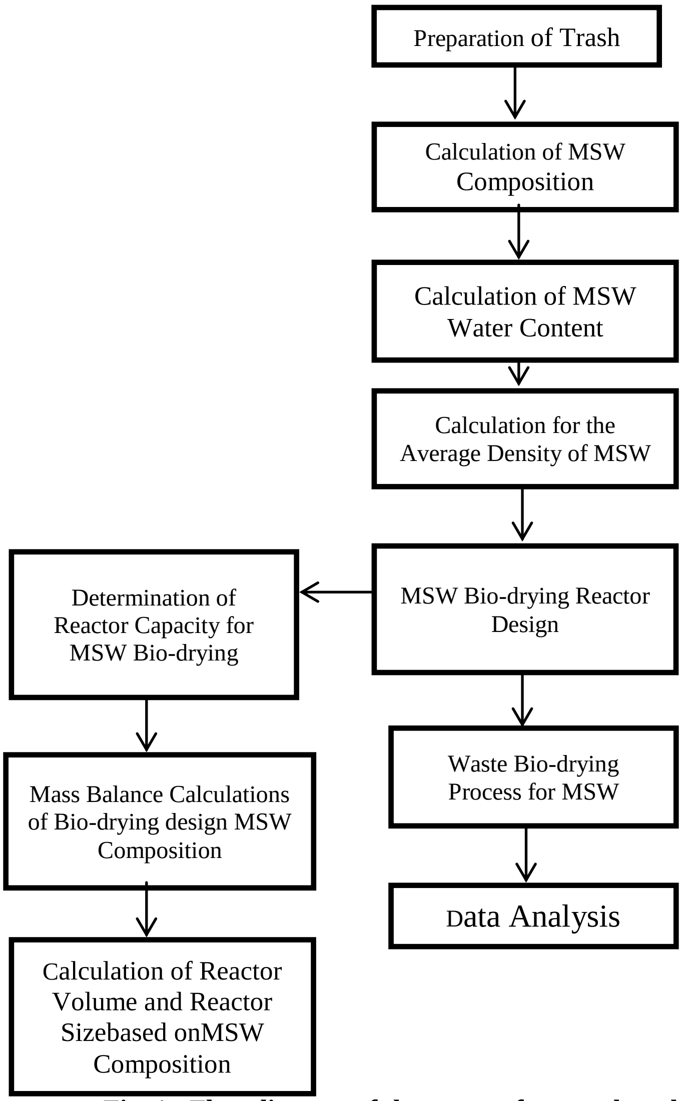


Fig. 1: Flow diagram of the stages of research and design

4. Calculation average mass of MSW

- Sampleof each group was taken by its fibre
- Sample of garbage was put in the beakerglass for each group based on fibre
- The volume of garbagewas recorded by each group of waste based on fibre
- Waste mass wasweighed for each group based on fibre
- Density of the average rubbish was calculated

5. Design Reactor

- Determination of the equipment shape (shown in figure 2)
- Determination of capacity and the results to be achieved with optimization operating conditions which were determined based on the results of existing research.
- Calculation of the mass balance
- Calculation of the reactor volume and reactor size

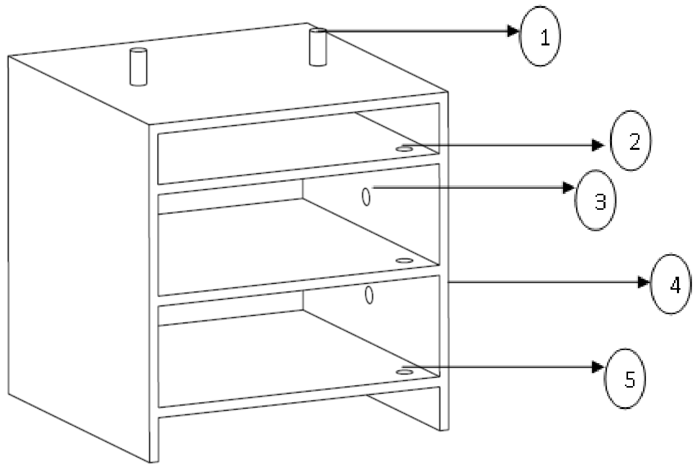
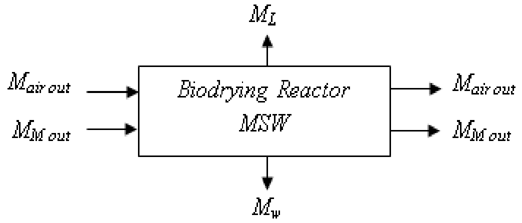


Fig. 2: Flowchart stages of research and design

Description:
1. Vent out
2. Tray form of woven wire
3. The air circulation holes
4. Wall
5. The incoming air circulation holes

5.1 Reactor Design

Designing is an activity plan, in this casethe process tool to create products, especiallychemical materials. The reactor is a place or venue for a reaction to take place. Bio-drying reactor use a process of physical and biochemical techniques. On the biochemistryside, aerobic biodegradation of organic matter is easily occursand cause decomposition and production of thermal energy (exothermic). On the physical side, convective moisture removal is achieved through control of excessive aeration. (Anonymous (5), 2012).
The volume of the reactor was determined using a formula:
Volume (m^3) = mass of wet waste (Kg)/average density of waste (kg/m3)
The mass balance of the process biodrying:



$$\int_0^{\tau\,end} M_{air\,in}(\tau)d\tau + M_{M\,in} = \int_0^{\tau\,end} M_{air\,out}(\tau)d\tau + M_{M\,out} + M_W + M_L$$

Where:

$M_{air\ in}$ = intake air mass contained in inflow
$M_{air\ out}$ = mass of air in the outflow
$M_{M\ in}$ = mass of entry waste
M_{Mout} = mass of dry waste
M_W = Mass of Lye
M_L = mass of lost

Designing a chemical reactor should give a priority to the efficiency of reactorperformance in orde to makethe products is largerthan the input with minimum capital and operating costs. It is also beared in mind that any safety factor must be taken into account. Operating costs typically include the amount of energy that would be given or taken, the price of raw materials, wages operator, etc.

Batch Reactor is a place for single occurrence of a chemical reaction, the reaction takes place with only one rate equation is paired with the equilibrium equation and stochiometry. Reactors of this type are usually very suitable for the production of small capacity, for example in the process of dissolving solids, blending products, chemical reactions, batch distillation, crystallization, liquid-liquid extraction, polymerization, pharmaceutical, and fermentation.

input = output + lost + accumulation

Or

(the rate of the reactants in the reactor is lost due to chemical reactions) = - (A rate of accumulation of reactants in the reactor)Eq. 1

A loss of reaction, $molortime(-rA)V = \left(\frac{molreaksiA}{(time\ )(volumeoffluid\ \ )}\right)(volumeoffluide)$
accumulation of A,$=\frac{dNA}{dt} = \frac{d[NAo\,(1-XA)]}{dt}$ = mol/time

By replacing these two equations in equation 1, we obtained

$$(-rA)V = NAo = NAo\frac{dXA}{dt}$$

By changing the position and then the integral gain

$$t = NAo\int_{0}^{xA}\frac{dXA}{(-rA)V}$$

Design of bio-drying process was carried out by considering several factors: process design, monitoring and control. Specific design and operational selection include:

a. Resistance to air flow was carried out by conditioning the trash matrix including size reduction and mixing (rotating drum reactor (Velles *et al*., 2009).
b. Reactor bio-drying was closed, to get a good insulating effect and compaction.
c. Reverse aeration system was used to reduce the gradient. (Velles *et al*., 2009; Sugni *et al*., 2005).
d. Setting of aeration control system from the waste matrix was used to determine the necessary for oxygen on that process and remove water vapour and off-gas.
e. Temperature, due point or relative humidity were controlled to increase the capacity for holdingwater vapour, as well as combined with the recirculation process.
f. Biochemical and physical processes were controlled with variable residence time in the reactor.

5.2 Calculating Volume Reactor

Volume = mass/ρ (average) Discharded

A (m^2)	S (m) (trial)	H (m)	H/S (target 1,5)
0.52	0.72	1.08	**1.50**

Volume MSW (m^3)	=	0.28 m^3	278.23 L
Free space	=	50.00 %	
Vol. Reaktor	=	0.56 m^3	556.46 L
1 Gal = 3.79 liter			

BIO-DRYING PROCESS

1. Treatment Research

In this research, bio-drying process was using 50 kg of waste MSW by matrix treatment of waste in a static condition and the condition is inverted once every 3 days manually. Air flew continuously into the reactor with the rate of 125 L/h using a hose. Thr air wss divided by 3 and put it into the reactor in each tray. Bio-drying process was carried out for 15 days. Used air was the air coming from the compressor, which was the air passed to watertrap before it is inserted into the reactor

2. Sampling and Analysis Methods

Analysis performed on the garbage was the analysis of the microorganisms content, analysis of trash water content, analysis of CO2 gas, and temperature measurements during the bio-dryingprocess. Analysis for the content of microorganisms in the trash that performed before and after the process bio-dryingon day 14, the analysis of the content of these microorganisms only to the observation of colony types, forms of bacteria, and gram stain bacteria. Analysis of water content in the trash before and after the bio-drying process was using gravimetric methods. To determine the amount of solid volatile, a calculation that refers to Kielydata was applied. For the analysis of gas CO_2that had been produced,it was absorbed using NaOH solution and then analyzed by titration methods. Inlet air temperature and the air temperature in each tray were measured every 24 hours, using asa thermometer for wettemperature (Tw) and also dry temperature (Td).

III. RESULTS

1. Calculate the waste composition

Component	*Volatile Solid (VS)*	*Lignin content (LC)*	*Biodegradable*
	% of Total Solid	*% VS*	*Fraction (BF)*
Food Waste	11	0,4	0,82
Paper			
Newsprint	94	21,9	0,22

Organic Waste	Mass (Kg)	Mass fraction (x)
Food Waste	37.5	0.75
Yard Waste	12.5	0.25
Total	50	1

2. Looking Density Trash

Organic Waste	Volume (M^3)	Waste mass (Kg)	☐ *Discharded* (Kg/m^3)	ρ_{Di} . *Xi (Kg/m3)*
Food Waste	0.001	0.18	182.37	136.77
Yard Waste	0.001	0.17	171.73	42.93
ρ Discharded (rata-rata)= ρFraksi(Xi)				**179.71**

3. Characteristics of *MSW*

Garbage has physical and biological properties. That wastes were used in this study were derived from Dinoyomarket, Malang and waste from Polinema campusyard. From the organic waste separation, we obtained that the composition of the waste consists of 75% foodwasteand 25% yardwaste, with the average water content of MSW was 74, 25% -75.18% and the average bulk density was 75.177 Kg/m3. The biological nature of this waste that refers to the Kiely theory below.

Biological properties of trash (Kiely, 2000)

Component	*Volatile Solid (VS)*	*Lignin content (LC)*	*Biodegradable*
	% of Total Solid	*% VS*	*Fraction (BF)*
Food Waste	11	0,4	0,82
Paper			
Newsprint	94	21,9	0,22
Office paper	96,4	0,4	0,82
Cardboard	94	12,9	0,47
Yard Waste	70	4,1	0,72

Table 1. Data of MSW

IV. DATA ANALYSIS RESULTS

Research data analysis, including measurement and calculation as follows:
- Flowrate of air in and air out of the flux were measured
- The temperature of air in and air out of the reactor were measured
- Mass leachate wss weighed and measured(the leachate volume which generated from incubation)
- Mass of wet waste and dry waste wereweighed
- Calculation of the mass balance
- Calculation of reduction waste humidity

Data Analysis Results

A. Before Biodrying

Table. 1 Data before Biodrying

Analysis	**Run 1**	**Run 2**
Trash mass (kg)	50	50
Water content (kg)	75,18%	74,25%
Water (kg)	37,588	37,126
Total Solid (kg)	12,412	12,874

B. After Biodrying

Table2. Data after Biodrying

Analysis	**Run 1**		**Run 2**	
	Target	**Experiment results**	**Target**	**Experiment results**
Mass trash (Kg)	22,7261	36,4490	22,9590	42,9590
MassLeachate (kg)		12,5680		6,2980
Air entrained water (kg)	0,4595	0,4947	0,4595	0,5082
Mass Loss (kg)		0,4883		0,2348
Exit masses (kg)	27,2739	13,0627	27,0410	6,5328
The remaining water in the trash (kg)	12,0869	24,4383	11,8417	30,0420
Water content %	53,185	67,971	51,577	70,769
CO2	56,1 gram		37,4 gram	

RESULTS AND DISCUSSION

The results of organic separationis waste composition consists of 75% foodwasteand 25% yard waste, with the average of water content of litter MSW is 74.25% -75.18%. The waste volume which is used is the result from the division of the waste mass with bulk density from organic waste instead of particle density. Bulk density is defined as the mass of many material particles divided by the total volume that they occupy. The total volume includes particle volume, inter-particle of empty volume and an internal pore volume. The particle density is the weight of the dry particle per unit the volume of material particles (so it isn't including pores) (Anonymous (5), undated).

Table. 2.1 Data Analysis Results Process Biodrying

Parameter			***Biodrying 1* (Without treatment)**	***Biodrying 2* (Inverted every 3 days)**
Before Process	*Biodrying*	MSW mass Beginning (Kg)	50	50
		Initial Water Content (%)	75,177	74,252
		Air mass Beginning (Kg)	37,588	37,126
		Total mass of Solid Start (Kg)	12,412	12,874
AFter Process	*Biodrying*	Massa MSW Final (Kg)	34,095	41,211
		End Water Content (%)	68,213	70,769
		Air masses End (Kg)	23,257	29,165
		Total mass of Solid End (Kg)	10,838	12,046
		Ratio Water / Solid Loss	9,106	9,617
		Total CO2 for 14 Days (g)	44,88	29,92

MASS BALANCE OF EXPERIMENT 1 (50 KG)

$$M_{air\ in} + M_{M\ in} = M_{air\ out} + M_{M\ out} + M_W + M_L$$

Input			**Output**		
Massa trash	50	Kg	Massa trash	34.095	Kg
Air Dry	28.719	Kg	Air Dry	28.719	Kg
Steam	0.337	Kg	Steam	0.832	Kg
			Output Lindi	13.102	Kg
			Missing mass	2.308	Kg
Total Input	**79.056**	**Kg**	**Total Output**	**79.056**	**Kg**

C. Agitation influence on the Bio-drying process with Microorganisms Activities

The energy required for the evaporation (latent heat, or entalpy evaporation) and any additional hygroscopic if the limit is reached, providedby aerobic biodegradation. Otherwise, the conventional drying use an external heat source. Aerobic decomposition of organic material by microorganisms exothermic biochemical transformations that can quickly raise the temperature of the matrix for thermophilic range. Increased temperatures can occur rapidly in a pile of garbage. One variable for bio-drying process is the using of agitation/rotation matrix waste in a dynamic reactor for homogenization, to achieve the same conditions; for example, by rotating drum reactor. (Velles al., 2009). The advantages by using the agitation or rotation according to Kyriakos H (2009) are:

- Increase the activity of microorganisms and produce the heat at low water level.
- Reducethe processing time
- Increase the reduction of particle size
- Increase the homogeneity of the final product (Kyriakos H, 2009)

In this study, agitation is done manually, by opening the lid of the reactor and then the garbage which stay on the inside of the bio-drying reactor,inverted by a tool such as a shovel wood every 3 days.

V. CONCLUSIONS

The residence time in the reactor is used as the basis for calculation of reactor design, which optimum residence time in the reactor static and dynamic is relatively similar therefore it does not affect the design. Influence can be seen in the conditioning bins with inverted every 3 days may increase the activity of microorganisms in the bio-dryingprocess. The amount of leachate in the dynamic reactor is more than the static reactor. This indicates a higher level efficiency in a dynamic reactor.

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