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Treatment of Waste Water from Organic Fraction Incineration of Municipal Solid Waste (MSW) By Evaporation-Absorption Process

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Abstract: Evaporation is one of treatment alternatives of waste water from condensation of vapour in flue gas or from flue gas scrubber system of an incinerator. The waste water contains tar and heavy metals which are toxic and must be separated, before discharged to environment or recycled. Due to the relatively low efficiency of the evaporation process, a combination of the evaporation-absorption process is developed to increase the efficiency. The aim of this research is to study the separation efficiency of tar from the tar-water mixture from organic fraction incineration of garbage by evaporation-absorption process, and compared it with the evaporation process. The evaporation process was performed by evaporating the waste water directly, while the evaporation-absorption process was carried out by evaporating the waste water before it had been mixed with palm oil as an absorbent. The results showed that the efficiency to separate the heavy tar of the evaporation process was 73.27% compared to the combination of evaporation-absorption that was 98.82%. Meanwhile, for the separation of the light tar, the efficiencies of both process types were almost the same. This system can be integrated with the incinerator for the treatment of flue gases and waste water generated from the burning of organic fraction of MSW.

Keywords:- Combination, Evaporation, Incinerator, Tar, Waste Water

I. INTRODUCTION

The land for the disposal of municipal solid waste (MSW) in Malang, Indonesia decreases with the increasing volume of waste. Based on the data from the department of hygiene and landscaping (Dinas Kebersihan dan Pertamanan, DKP) of Malang, average daily waste volume is 1100 m3 (459 tons). The largest component is the organic fraction, from kitchen waste and yard waste which is 76.2%. A large part of the garbage is dumped on open land and only a small part of about 3% is recycled for compost or other. The volume of residual waste that is not utilized is large, and can cause environmental problems and the provision of land disposal if no adequate treatment.

Based on calculations, for a period of 10 years the needs of the area for disposal of garbage by volume as mentioned above with a pile height of 10 m, is 15 ha [1]. It is difficult to provide land area, due to limited available land. Therefore, another alternative of waste management system should be considered. Incineration may be chosen as an alternative option to replace the open dumps system, because it can reduce by 90% the volume of waste in a short period [2]. Constituent components of the organic waste are mostly leftover food (palms, fruits) and crops [3]. The main component constituent of food: proteins (polymers of amino acids), fats (lipids, carboxylic acids), carbohydrates (mono and oligo and polysaccharides), fibre (polysaccharides such as cellulose and lignin), vitamins, and minerals (Ca, P, Fe, Na, K Cu, Mg, Mn). The chemical composition of each constituent depends on the type of waste organic materials. The garden plants consist of grass., leave twigs, stems with its major components: cellulose, hemicellulose and lignin.

Thermal degradation of the fibre material produces brown tar-containing compounds with high molecular weight. Approximately 60-70% of the total tar dissolved in water and contains a compound with a lower molecular weight. Guaiacol compounds are the main products of thermal degradation of lignin. Other compounds with a lower molecular weight and easily dissolved in water include: phenol, cresol, quinoline and pyridine [4]. In addition, thermal process also produces pollutants such as SO_2, NH_3, H_2S CO, CO_2, HCl, particulate matter (PM), tar, soot, NO_x, volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAHs), heavy metals, dioxins, and furans in the exhaust gas [5,6]. The components of these pollutants must be separated from the flue gas before it is released into the atmosphere.

Wet scrubber is a method widely used in the contaminants separation from the flue gas [7-9]. Wet scrubber process generates waste water mixed with inorganic and organic compounds derived from exhaust gas components, and absorbed by the water as contaminants. The main component of the organic compound is tar while the inorganic are: acid; salt; and heavy metals [10]. These compounds in the water can be toxic and carcinogenic, and should be separated from waste water before discharge into the environment or be recycled [11].

Several methods of the waste water treatment can be used, namely physical, chemical and biological [10, 12, 13]. Disadvantages of physical processes are only suitable for early treatment and cannot be used independently (must be combined with other processes), chemical processes require a high cost, and biological processes are not effective because the metabolism of microorganisms disturbed by the toxicity of tar. In addition, water from the physical and chemical treatment still contains a neutral salt [14].

Thermal process (evaporation, distillation, stripping) is an option that can be applied to replace the previous three processes. The advantages of thermal processes, it can produce water that is free of soluble chloride salt, so it can be disposed or recycled directly without further processing [15]. The application of the thermal process is only effective if the requirements heat energy for vaporization comes from the heat content of the garbage itself. The heat energy required to evaporate the water can be supplied from some of the heat from the combustion of waste. Three European countries (Germany, Austria, and the Netherlands) have been implemented evaporation method for incinerator waste water treatments, but the application just for large capacity and use of complex equipment. Applying this technique on a small scale combustion requires expensive cost of investment and operation as well as the difficulty of obtaining information on the technical data of the process (from open source literature). Stantec reported a method to treat wastewater from the combustion of solid waste by evaporation, to produce the condensate water with low heavy metal content, but there is no detailed description of the process [16]. Several studies have been conducted, to study the separation of tar from the gasification product gas through the absorption process using oil, but no further information on the application of this technique for the separation of tar from the water [4, 17].

This paper presents a research report on the processing of waste water from organic fraction incineration of MSW by a combination process of evaporation - absorption. This technique can improve the quality of treated wastewater, compared to evaporation. When compared visually, the appearance of condensate from the evaporation-absorption process is clear and colourless, while the condensate product of evaporation, more cloudy with light green colour. In this study the used of palm oil as an absorbent, due it can absorb the tar in the exhaust gases from incineration with high efficiency, 99% [17]. This study used an assumption that the palm oil efficiency on the tar absorption in the tar-water mixture, almost the same as the absorbing efficiency of tar in the exhaust gas. The Results from this study can be used as a reference for waste water treatment from organic fraction incineration of MSW. This technique is being developed to be integrated with the air pollution control systems at the small-scale incinerator in the city of Malang.

II. MATERIALS AND METHOD

2.1 Experimental Material

Municipal solid waste samples was taken from the temporary waste collection (TPS) Tlogomas, Malang, Indonesia, and had been separated of the inorganic components, which includes paper, plastic and metal, so all that remains was the organic fraction. The fraction of the organic waste was burned without drying. Therefore, the water content of garbage was still relatively high (30-55%). Characteristics of garbage based on proximate analysis and the estimation of elemental composition by calculation was shown on Table 1.

Table 1: Typical Proximate and Elemental Composition

Analytical parameter	Value (%)
Proximate Analysis	
Moisture	51.66
Ash	17.46
Volatile	62.49
fixed carbon	20.04
Elemental Composition*	
carbon	43.13
hydrogen	5.11
oxygen	35.75
HHV (kcal/kg)	3802.42

* Calculated

2.2 Experiment Methods and Conditions

Incineration waste water was obtained from the condensation of condensable component in the exhaust gases from the burning of organic fraction of garbage. The waste was burned in a batch manner, a total of 3 kg of waste per batch burned using liquefied petroleum gas (LPG). Leaving the incinerator the exhaust gas temperature was 383 ^{o}C and the condenser was 43 °C. The exhaust gas then was cooled, and the condensate was collected in the tank. The scheme of the combustion process equipment was shown in Figure 1 [18].

The waste water then was evaporated on the evaporation apparatus (Figure 2) with two methods, evaporation and combinations. Evaporation process was conducted by evaporating 50 ml of wastewater, while the combination process by evaporating a mixture of 40 ml of waste water and palm oil at a ratio of 1:1 (volume). Evaporation was conducted at a temperature of 99 °C and atmospheric pressure, up to 80% (volume) of the sample evaporated. The evaporation process then was stopped due to residue in the reservoir has been difficult to evaporate.

The vapour of both types of the process was condensed and further analysed to determine pH, concentration of light and heavy tar, and metal. The pH analysed using litmus paper, a gravimetric method for the analysis of heavy tar, LCMS for analysing the light tar and for metal (Na, K, Cu, Pb, Cr, As, Hg and Zn) used atomic absorption spectrophotometer (AAS). The concentration of tar and heavy metals expressed in mg / l, the concentration of the light tar in units of % relative. The Unit % relative defined as the ratio of the peak area tar components and the peak area of the reference components (nonifamide) on LCMS analysis. Tar concentration of both condensate before and after the evaporation process was then compared to determine the efficiency of the process, which was calculated by equation 1 [17] .

$$\frac{C_{wastewater}^{tar} - C_{condensate}^{tar}}{C_{wastewater}^{tar}} \times 100\% \quad (1)$$

with, C was concentration

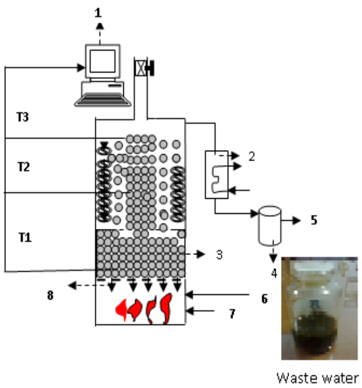

Fig.1: Illustration diagram for the incinerator. 1: temperature monitor; 2: condenser ;3: incinerator; 4: waste water tank ; 5: flue gas; 6: primary air ; 7: LPG; 8: ash; T_1, T_2, T_3 waste bed temperature.

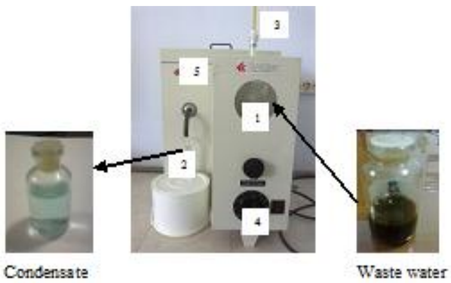

Fig. 2: Evaporation equipment. 1:waste water tank; 2 condensate tank;3: thermometer; 4 :temperature regulator; and 5: condenser.

III. RESULT AND DISCUSSION

The temperature profile of organic fraction incineration of the garbage to produce waste water can be shown on Figure 3. The condensate water collected is 150 ml for every 1 kg of the wet garbage incineration. The volume of condensate water is smaller than the average water content of waste that is reaching 51.66% (mass) because not all of the water vapour in the flue gas was condensed. As shown in Figure 4, T1, T2 and T3 is the temperature of the combustion zone gas, pyrolysis zone and drying zone respectively. In this study, the highest gas temperature of 383 °C, with the tar and water as dominant product. These characteristics are consistent with the results of research conducted by Wang, that concluded that the liquid products of pyrolysis of solid domestic waste at a temperature of 300-700 ^{o}C dominated by tar and water [19]. The analysis result of the condensate from the incinerator is presented on Table 2. The visual appearance of the wastewater before and after processing by evaporation and combinations is shown in Figure 4, while the concentration of heavy tar in wastewater before and after the evaporation process is shown in Figure 5.

Table 2: Analysis of Waste Water

Component	Characteristic
Color	Turbid, dark brown
pH	11-12
Heavy tar (mg/l)	45000
Metal (mg/l)	
Na	121,0
K	120
As	Undetectable
Cu	1,896
Cr	<0,0204
Hg	0.0001
Pb	0,007
Zn	1,973

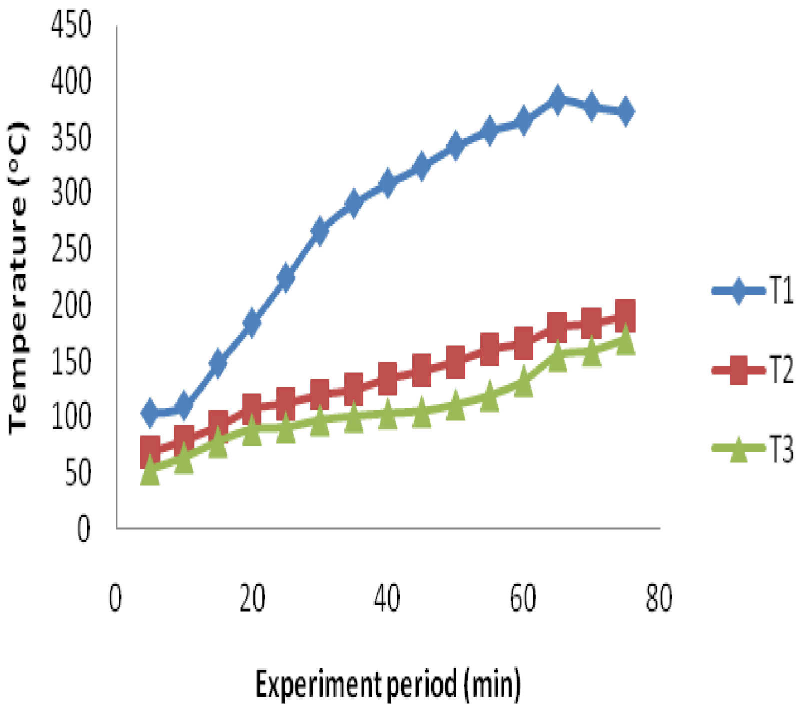

Fig. 3: Incineration temperature profile of organic fraction of garbage

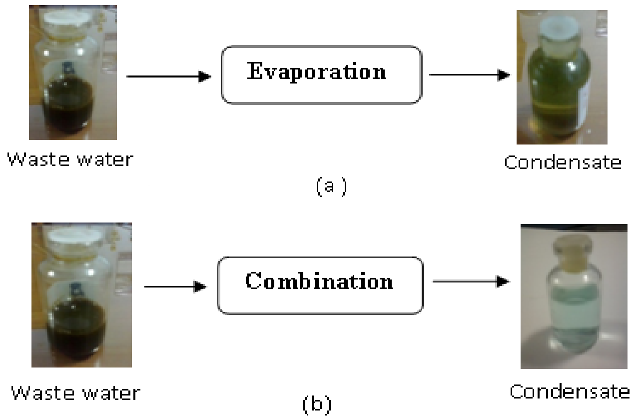

Fig. 4: Waste water before and after treatment, (a) evaporation and (b) combination

As shown in Figure 4, the appearance of the waste water is turbid and dark brown colour. The colour of the waste water is turbid and brown due to the high content of the heavy tar (pitch) and fragments of biomass in the water. Condensate from evaporation process (Fig. 4a) is a yellowish green colour, while the condensate from the combination process (Fig. 4b) is clear and colourless. The evaporation process produces condensate which containing heavy tar higher than the combination process, due to the vaporization of the heavy tar at the boiling point of water and then mixes with water vapour. On the combination process, the tar vapour has absorbed first by the palm oil before to be condensate and therefore the concentration of the heavy tar on the combination process is low. The tar concentration in the wastewater before and after treatment respectively was 45000, 10700 and 470 mg / l for waste water, condensate from evaporation, and condensate from the combination process (Fig. 5)

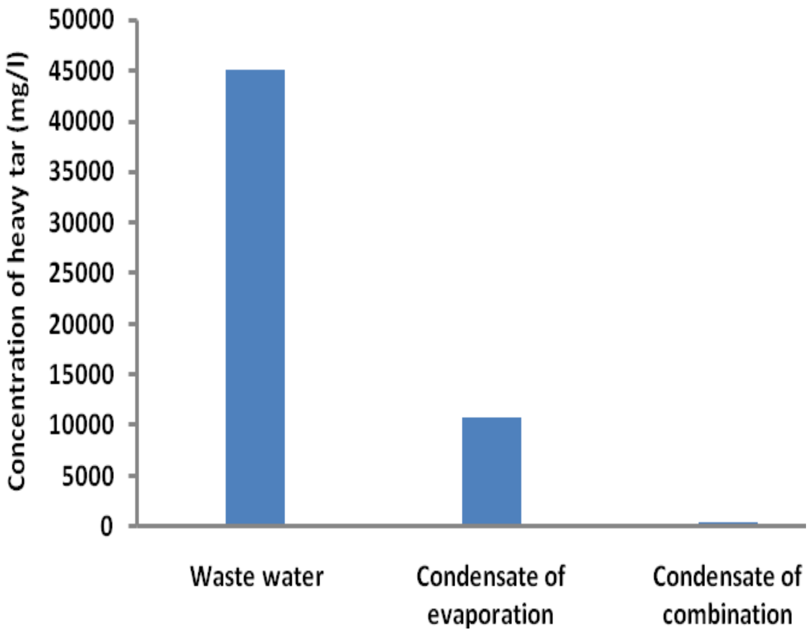

Fig. 5: Concentration of heavy tar on the: waste water, condensate of evaporation, and condensate of combination

In contrast to the effectiveness of the separation of heavy tar, where the combination process is better than the evaporation, the efficiency of combination process and evaporation process to separate the light tar are almost same. As shown at Figure 6, the relative concentration of the light tar with a molecular weight in the range of 94-635 on the condensate as well as the efficiency of the process (Table 3), at the both process are the same almost. The light tar have a relatively low boiling point and more volatiles than the heavy tar, and although has been absorbed by palm oil it can be easy be separate again from the oil, due to the steam stripping. The light tar then carry over and be mix with steam, and was condensed as condensate. This phenomenon is causing a light tar separation efficiency on the combination process is almost the same as compared to evaporation process. The another phenomenon is the combination process efficiency - 27.76% (3rd column of Table 3) at the separation the tar with a molecular weight of 79.50 to 80.50, this condition shows that the tar in the condensate is greater than the tar in the waste water. The possibility is, that there is a volatile component of palm oil that carry over by water vapour on the stripping process, so adding the concentration of tar with a molecular weight of it, on the condensate

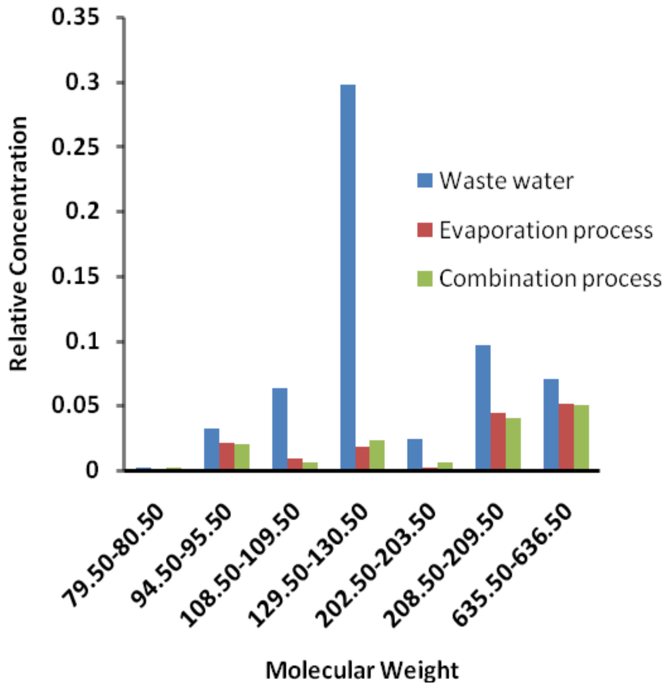

Fig 6. Relative concentration of the light tar at the water before and after treatment process

Table 3: Efficiency of the Process

Molecular Weight	Evaporation (%)	Combination (%)
79.50 – 80.50	25.11	-27.76
94.50 – 95.50	33.82	37.72
108.50 – 109.50	86.27	90.57
129.50 – 130.50	93.85	92.14
208.50 – 209.50	92.17	72.95
235.50 – 236.50	54.23	57.93
635.50 – 636.50	26.39	28.49
Heavy tar	73.27	98.82

In general, based on the characteristics of the water condensate (colour, separation efficiency), the combination process is better than the evaporation process. The characteristics of incinerator waste water product of the combination process, the legal limits of industrial wastewater in Indonesia, Austria and the Netherlands incinerator waste water are listed on Table 4.

Table 4: Waste Water Parameters before and after Treatment by Combination Process

Parameter	Before treatment	After treatment by combination process	Indonesia limits[a]	Austrian MSW incinerators [b]	Dutch MSW incinerators[c]
pH	11-12	9	6-9	6.8-8.5	-
Gravimetric Tar				-	-
(mg/l)	45000	470	-	-	-
Metal (mg/l)			-	-	-
Na	121	23.5	-	-	-
K	120	0.167			
As	N.A[d]	N.A.[e]	0.1	<0.003-<0.05	0.01
Cu	1.896	1.326	2.0	<0.05-<0,.3	0.02
Cr	<0.0204	<0.0204	0.5	<0.05-<0.1	0.03
Hg	0.0001	0.0001	0.002	<0.001-<0.01	0.005
Pb	0.007	N.A.[f]	0.1	<0.01-<0.1	0.10
Zn	1.973	0.037	5.0	0.050-0.500	0.20
[d,e,f] N. A :not available					

[a] Regulation State Ministry of Environment of Indonesia. No: KEP-51/MENLH/10/1995
[b] Federal Environment Agency-Austria 2002. State of the Art for Waste Incinerations Plant
[c] Ministry of Housing, Spatial Planning and the Environment 2002. Dutch Notes on BAT for the Incineration of Waste.

As shown in Table 4, the chemical characteristics parameter of the process combinations meet the requirements of the quality standards of Indonesian industrial wastewater discharges, so that this method can be applied to the treatment of waste water from organic garbage incineration..

IV. CONCLUSION

In this study, the efficiency of tar separation from waste water from organic fraction incineration of MSW by evaporation method and a combination of evaporation - absorption have been measured. Both of these processes can be applied to separate the tar from the waste water of organic fraction incineration of garbage. The efficiency in separating of heavy tar of the evaporation process is 73.27% compared to the combination of the evaporation-absorption that is 98.82%. The combination process produce the condensate which is clearer than the evaporation process. Based on the color of the water and the concentration of heavy tar in the water, the process of combination is better than evaporation. The combination process generates waste water which meets the specifications of Indonesian industrial waste water.

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