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Effect Of Organic Household Waste Tar Removal By Condensation On The Flue Gas Composition

[1,] Subagiyo, [2,] Eko Naryono, [3,] Sandra Santosa
[1,] *Mechanical Engineering, State Polytechnic of Malang, Indonesia*
[2,3,] *Chemical Engineering, State Polytechnic of Malang, Indonesia*
Soekarno Hatta No. 9 Malang

***Abstract**: Condensation is an alternative methods of tar separation on solid waste combustion systems. This research studied the effectiveness of this method to reduce CO, CO2 and hydrocarbon (HC) in the exhaust of combustion gases of household waste with various moisture content. The results showed that the separation of tar does not affect the concentration of CO, CO2 and low boiling point hydrocarbons. From the results of qualitative analysis at condensate, showed compounds like hexana, cyclopentan, phenol, p-cresol and guaiacol, Na, Ca (trace). The concentration of tar was 4.297% analyzed using gravimetric analysis tar, and the ash was 0.449%.*
***Keywords:** Gas emissions, Condensation, Combustion, Tar.*

I. Introduction

Combustion is one alternative household solid waste treatment that produce flue gases and contaminants. Household solid waste has a great volatile matter and water vapor. In the combustion process they are becoming a precursor to the formation of volatile tar and soot (Jinliang, 1996). Tar is one of the contaminants that should be removed from the flue gas before it is discharged into atmosphere. This component is a source of particulate matter (PM) that is harmful if inhaled (Jenkins et al, 1998) Solvent scrubber and thermal destruction are the techniques commonly used in many incineration plants to removed tar and contaminant (Phupuakrat et al., 2011, Zhang et al., 2010). However, this techniques requires high cost of equipment and also the operating cost so it makes less appropriate when applied on a small scale.Condensation is a simple method of tar separation technique. Theoretically, it can condense tar which has a boiling point above benzene. The water content in the waste affect the rate of evaporation of volatile materials, condensation and tar composition. When the flue gas was cooled, the tar and other contaminants that can be condensed will separate from the gas so it become more clean.The information of the effect of tar removal on the composition of flue gases is hard to find from the open literature in the recent year. Most of the operated incinerators, recycled the tar to be burned out. On fuels with high water content, this technique is not effective because it affects the continuity of combustion This research was studied the influence of the tar removal by condensation on the composition of CO, CO2 and HC in the exhaust gas of household waste combustion with various water content. The result was analyzed and discussed to view of the changes on gas composition, gravimetric tar and fly ash.

II. Methods

2.1. Experimental Facilities.

The experiments were run in a batch process by burning 1000 grams organic household waste (4) in a fixed bed incinerator as shown in Figure 2.1. The incinerator is a vertical cylindrical combustion chamber. The height of the chamber is 2.0 m with an inside diameter of 300 mm. The grate (5) is located at the bottom of the chamber and consists of mild steel wire screen. Five thermocouples were used to monitor three temperatures (T1,T2,T3) inside the bed with different height levels, temperature of flue gas and condensing temperature. All thermocouples were connected to a computerized data logger (1) to record the temperatures automatically. There is a gas-sampling probe outside the chamber of the incoming (3) and out going (9) condenser (8). An LPG gas burner (6) was used on the combustion process to maintain the temperature at 300^oC. The day light solar heat was used to vary the waste water content. Waste generated from the drying has a water content of 15.4 (8 days), 24.1 (6 days), 30.2 (4 days) and 40.4% (2 days).Incoming and outgoing gases were measured to be analyzed in order to see the changes of CO, CO2 and HC concentration. The condensate was qualitatively analyzed to see any organic compounds, metals, and the concentration of gravimetric tar and ash were measured quantitatively.

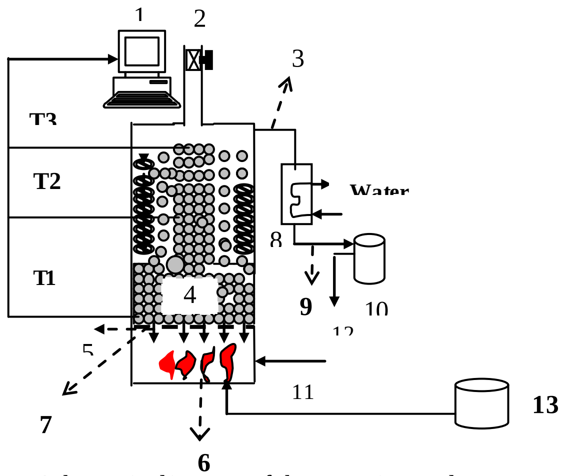


Fig. 2.1. Schematic diagram of the experimental setup

1. Temperature Monitor, 2. Feed, 3. Incoming gas probe, 4. Organic waste, 5. Grate, 6. Burner, 7. Ash, 8. Condenser, 9. Out going gas probe, 10. Tar Tank, 11. Inlet Air, 12. Exhaust gas, 13. LPG gas

2.2 Gas Analysis And Tar Determination

The released gas was analyzed by gas analyzer (Crotech QRO-401), whereas light hydrocarbon species was analyzed using GC/MS spectrophotometer. The concentration of heavy tar and fly ash from condensate was measured using gravimetric method.

III. Result And Discussion

3.1 Temperature Profiles

Temperature profiles of combustion (T1,T2,T3) can be seen in Figure 3.1a, b, c. It shows that as the moisture content getting lower, at the same interval time, T1 become higher. The highest temperatures reached at 15.4% water moisture content.

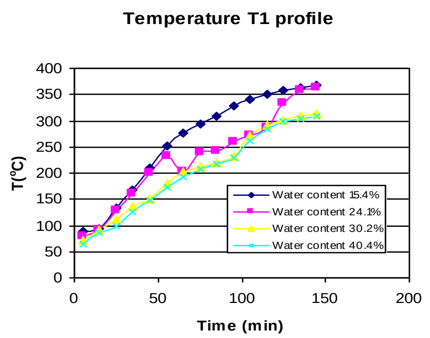


Fig 3.1a Temperature profil of T1.

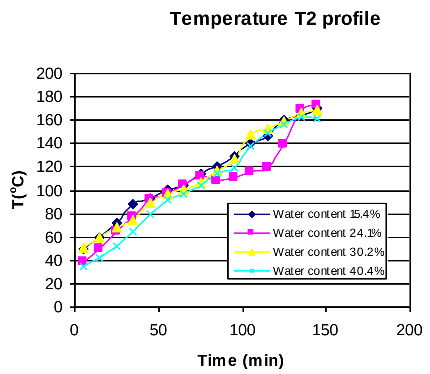


Fig 3.1b Temperature profil of T2.

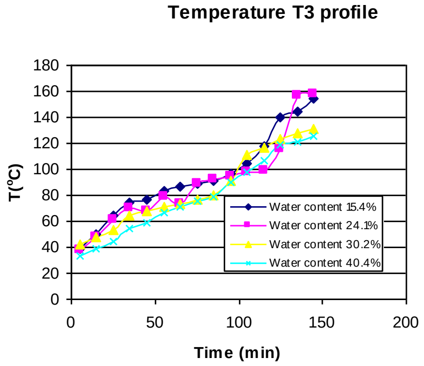
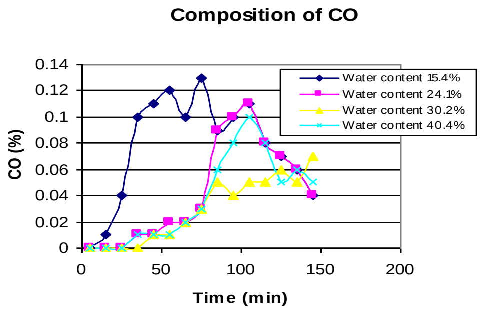


Fig 3.1c Temperature profil of T3

Temperature profile T2 and T3 (Figure 3.1b, c) have slightly the same figure with the T1 views that at the higher water content, the temperature drops. But compared to the temperature T1, the difference at each water content getting smaller. This is due to the T1 region, close to the combustion chamber so that the temperature is easy to change due to some of the water that falls down at the start of evaporation.

3.2 Flue Gas Composition

The effect of moisture content of waste on the composition of exhaust gases can be seen in figure 3.2a, b, c. In Figure 3.2 shows that the lower the moisture content the higher the CO composition. At the lowest of 15.4% of moisture content, which has the highest temperature profile, it is possible a pyrolysis process to occur and produces higher of CO gas, while on the water content of 24.1, 30.2 and 40.4% they are still in the stage of evaporation of volatile materials.



. **Fig. 3.2a** Composition of CO

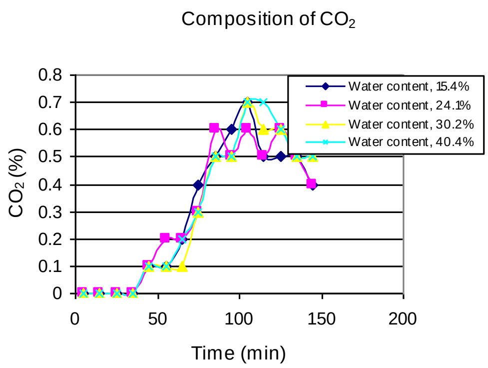


Fig. 3.2b Composition of CO_2

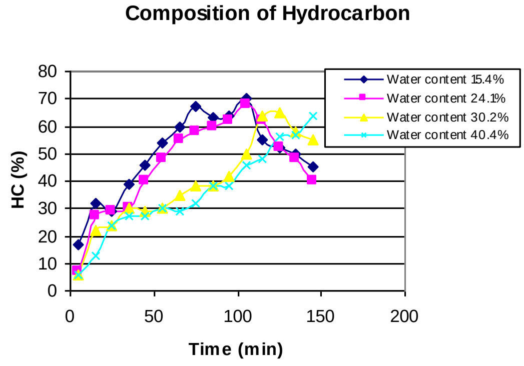


Fig. 3.2c Composition of hydrocarbon

The correlation is quite consistent compared to the results of Yang (2004). The composition of CO2 does not much influenced by the moisture content in the temperature range studied. This is due to the stage of devolatilization at 360^{o}C (peak temperature) whereas the process didn't influence the CO2 composition. The composition of hydrocarbons has reverse effected on the ratio of moisture content. The higher moisture content produces lower HC. The maximum concentration of HC achieved slower at lower moisture content. This is due to the highest moisture content and the devolatilization of volatile matter become slower to reach a maximum HC concentration. The time to reach maximum HC content is a function of moisture content and was done at 100, 105, 125, and 145 minutes.

3.3. Effect of Tar removal on Gas Composition

The effect of tar condensation on the composition of the exhaust gases can be seen in figure 3.3, 3.4, 3.5, 3.6 a, b, c. In Figure 3.3-3.6 shows the correlation of moisture content and gases compositions of incoming and outgoing gas to condenser.

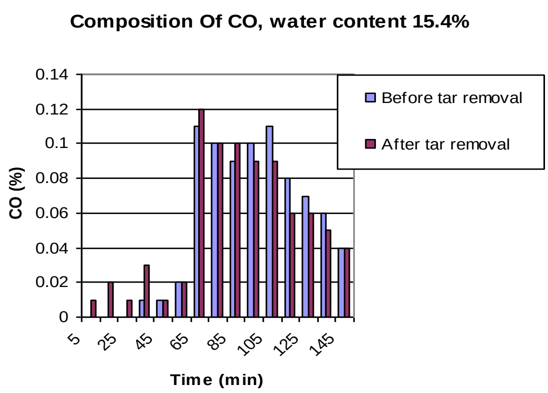


Fig 3.3a Composition of CO before and after tar removal, 15,4% moisture content

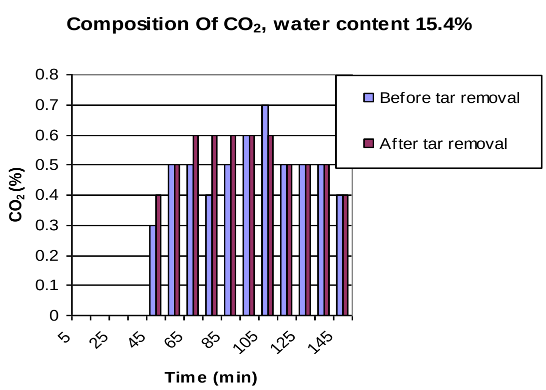


Fig 3.3b Composition of CO2 before and after tar removal, 15,4% moisture content

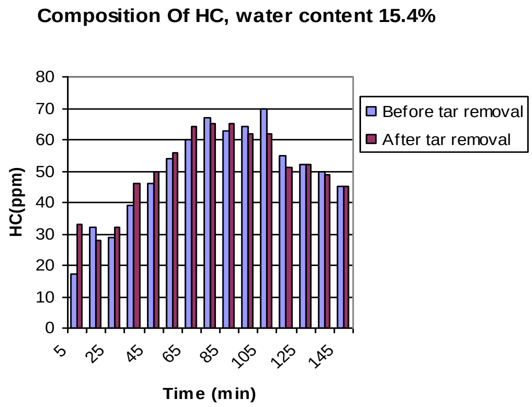


Fig 3.3c Composition of HC before and after tar removal, 15,4% moisture content

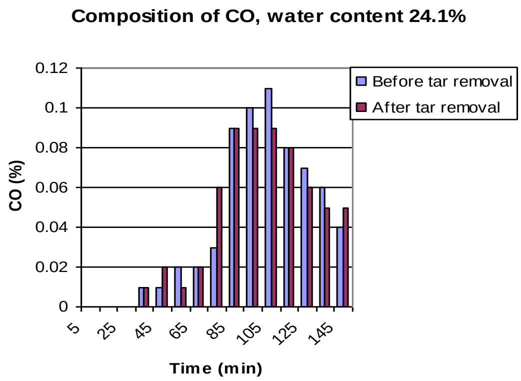


Fig 3.4a Composition of CO before and after tar removal, 24,1% moisture content

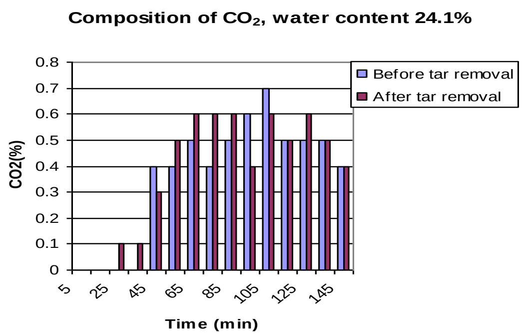


Fig 3.4b Composition of CO2 before and after tar removal, 24.1% moisture content

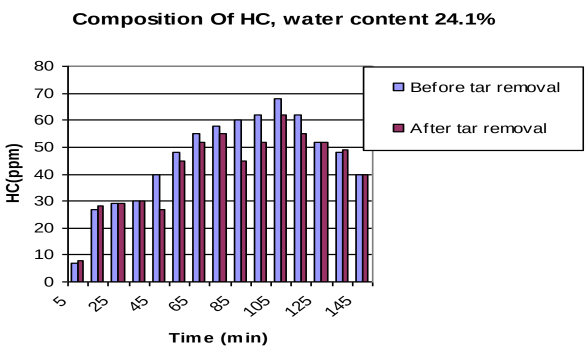


Fig 3.4c Composition of HC before and after tar removal, 24.1% moisture content

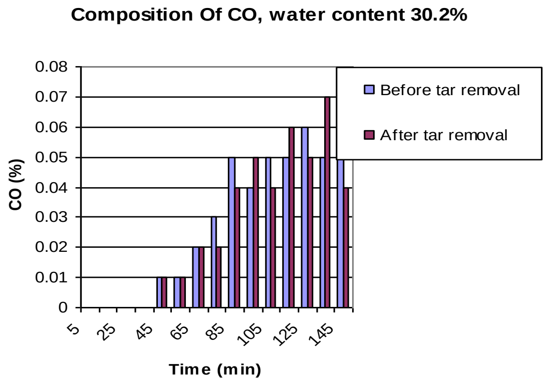


Fig 3.5a Composition of CO before and after tar removal, 30.2% moisture content

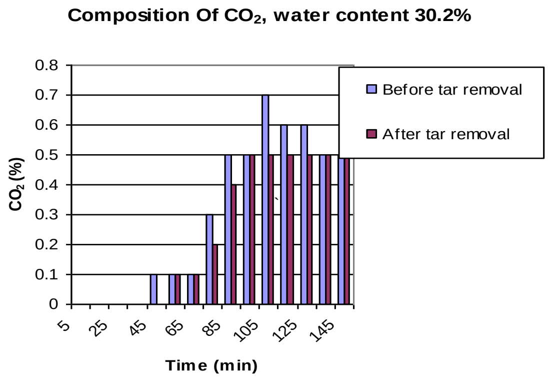


Fig 3.5 b Composition of CO2 before and after tar removal, 30.2% moisture content

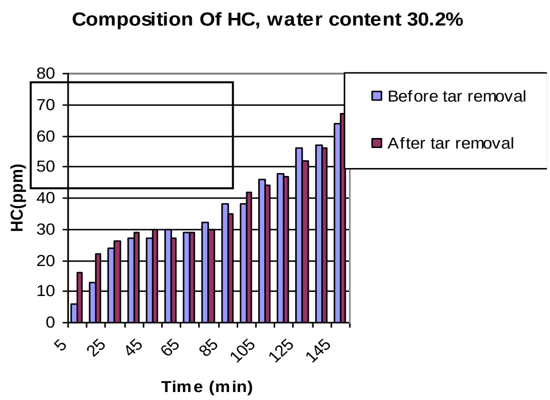


Fig 3.5c Composition of HC before and after tar removal, 30.2% moisture cntent

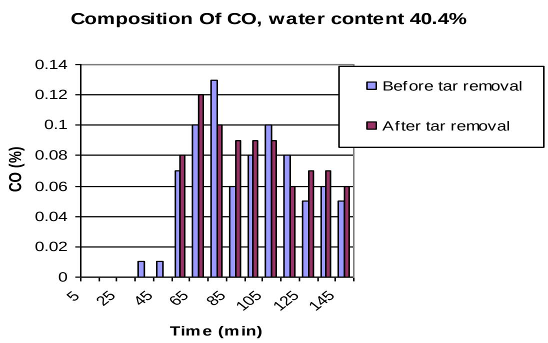


Fig 3.6a Composition of CO before and after tar removal, 40.4% moisture content

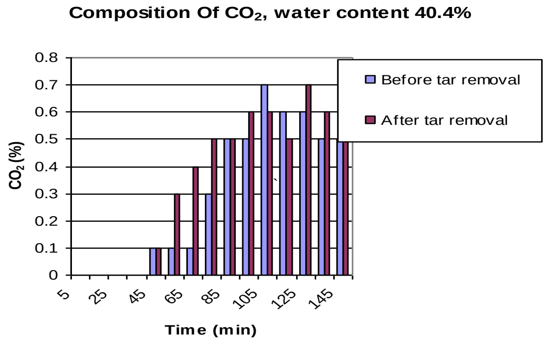


Fig 3.6b Composition of CO2 before and after tar removal, 40.4% moisture content

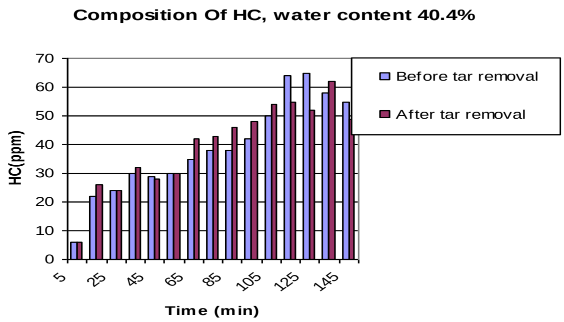


Fig 3.6c Composition of HC before and after tar removal, 40.4% moisture content

Based on these figure, it can be seen that almost any composition CO, CO2 and HC in the incoming and outgoing condenser, exhaust gas does not change. This is because the CO, CO2 are permanent gas so they can not be removed. Hydrocarbons are a light type compounds, so they could not condensed at the condenser exit temperature at 43^{o}C.During the combustion process, some heavy tar condensed in the combustion chamber and stuck to the wall at 153.7 ^{o}C. This type of heavy tar will condensed at 200-500^{o}C (Neves, 2011). Some light tar which has a dew point above the condenser temperature will condense and separated from the flue gas in the form of distillate.In order to evaluate the effect of the separation of tar on the combustion flue gas, condensate was analyzed qualitatively and quantitatively.. Based on the instrument analysis, resulting the organic compounds in the tar which are hexane, cyclopentane, phenol, p-cresol and guaiacol, and the inorganic compounds are Na, Ca (trace) whereas Cd and ash are negative. In average, a kilogram of waste produced tar mixed with water (pyrolitic water) were 203.3 grams, the tar concentration is 4.297% and ash 0.449% (at the conditions of studied).Based on these data it can be concluded that the separation of tar from the flue gas by condensation, could reduce potential pollutants of the above components. This data can be used as a basis for further research in reduction of pollutants quantitatively in more detailed.

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IV. Conclusion

In this study, the effect of the removal of organic household waste tar by condensation on the flue gas composition was evaluated. The evaluation focused on the effect of variable moisture content of waste on the composition of CO, CO2 and hydrocarbons in the exhaust gas after tar to be removed. Based on the results and discussion by analysis of the data presented in graphical form, the correlation between the variables studied with exhaust gas temperature, composition and analyzing the condensate, it can be concluded as follows:

1) The higher the moisture content in the waste, the combustion chamber temperature changes more slowly. This affects the rate of evaporation of volatile material of waste getting slower.
2) The lower moisture content produced higher CO and HC concentrations, while the concentration of CO2 almost constant.
3) Tar separation by condensation will be reduced the concentration of some of heavy types of hydrocarbons, Na metal, and particulate matter in the form of ash.
4) In general, the combustion of dried waste and tar removal can reduce pollutants in the exhaust gases.

V. Acknowledgements

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