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MICROWAVE ASSISTED PYROLYSIS (MAP) OF AUTOMOTIVE PAINT SLUDGE (APS)

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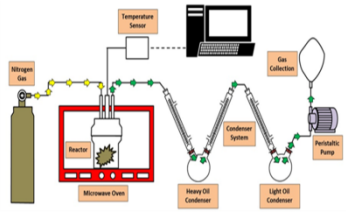
Graphical abstract



Abstract

Hazardous waste such as automotive paint sludge has a potential to be recovered or treated with advance method such as microwave assisted pyrolysis. It is an advantage for the process with the aid of microwave radiation to the system due to the high affinity of water in the automotive paint sludge which acts as the medium of heating in the microwave pyrolysis reaction. By having such process, not only it is good to dispose the automotive paint sludge but three different products have been recovered from that process such as solid char, liquid oil and gas. With the high hydrocarbon content in the automotive paint sludge, it was estimated that high valuable hydrocarbon might be recovered in the liquid product. From this research, three parameters were studied and analyzed for the product distribution and liquid oil recovered which are sample weight loading, microwave power level and radiation time. It was observed that best sample weight loading, microwave power level and radiation time to produce high liquid hydrocarbon oil were 200g, 1000W and 30 minutes respectively in which 0.1g or 0.27% was liquid oil recovered from overall sample weight loading.

Keywords: Microwave assisted pyrolysis, automotive paint sludge, hazardous waste, liquid oil

1.0 INTRODUCTION

Automotive paint sludge (APS) is a one types of sludge generated from car manufacturing company. It can be generated from Toyota, Honda, GM Motor, Ford, Proton or PERODUA or others. Production of automotive paint sludge waste commonly is based on the number of car produced by the car manufacturer. It is estimated about 40% of paint used might end up as the automotive paint sludge for each car produced [1]. With the increased of number of car on the road in the recent years, almost 200,000 kg of automotive paint sludge is estimated to produce annually. This number might increase and even worst with the haste of growth in the economic. This number might worry the environmentalist and government on how to dispose for such high number automotive paint sludge. Usually the APS is sent to an authorize disposal company and cost of disposal is high since the sludge is categorized as hazardous or schedule waste, SW 416 [2]. In the case of material with significant moisture content such as Automotive Paint Sludge (APS), microwave pyrolysis is suitable and it

offers a different mechanism in particle heating where the electromagnetic field penetrates the solid, and interacts directly with dipoles in the chemical structure. Due to the high affinity of water molecules with microwave, moisture content within a given sample particle is selectively targeted by incidental microwaves. Microwaves vaporize moisture in the depth of the particle, prior to volatilizing organic content. The steam generated is rapidly released into the surrounding area, not only sweeping volatiles, but also creating preferential channels in the carbonaceous solid that increase its porosity [3]. With microwave assisted pyrolysis technology implementation, valuable chemical in the form of liquid oil will be recover from automotive paint sludge and be the main focused in this paper.

2.0 MATERIALS AND METHODS

2.1 Microwave Assisted Pyrolysis of Automotive Paint Sludge

The sample that has been used in this study was automotive paint sludge (APS) that has been collected from the second larger automotive manufacturing company in Malaysia [4]. It was collected directly from the water wash chamber beneath the spray booth in the plant and it is in slurry form. Automotive Paint Sludge has high humidity characteristic which contains almost 50% of water. By using Microwave Assisted Pyrolysis Equipment, high humidity content in the automotive paint sludge can be injected directly to the sample container without any drying process. Sample was taken from sample container without any drying process needed. Sample was weighted and placed in the reactor. Characteristic of collected automotive paint sludge in proximate and ultimate analysis is shown in Table 1.

Table 1 Characterization of Automotive Paint Sludge (APS)

Sample Material	Automotive Paint Sludge	Literature [5]
Calorific value ($MJkg^{-1}$)	22.3 [4]	18.12
Ash (%)	28.8	22.7
Moisture (%)	38.3	29.9
Volatile (%)	22.2	75.2
Fixed carbon (%)	10.7	2.1
Ultimate Analysis[a]		
Carbon (%)	50.2	
Hydrogen (%)	4.29	
Nitrogen (%)	10.1	
Sulfur (%)	0.49	
[b]Oxygen (%)	34.92	
Chemical Composition	$C_{102}H_9N_{21}SO_{71}$	

[a]Calculated dry basis
[b]Calculated by difference

Microwave assisted pyrolysis of automotive paint sludge sample has been done under the assistance of microwave irradiation by using modified commercial microwave and is shown in Figure 1. Sample was placed in the quartz reactor and nitrogen gas with flowrate of 250 mL/min has been purged into the reactor for 10 minute before the microwave pyrolysis take place in order to obtain inert condition. During the microwave pyrolysis, flowrate of nitrogen is set to 150 mL/min and it is used as the carrier gas during the microwave pyrolysis [6].

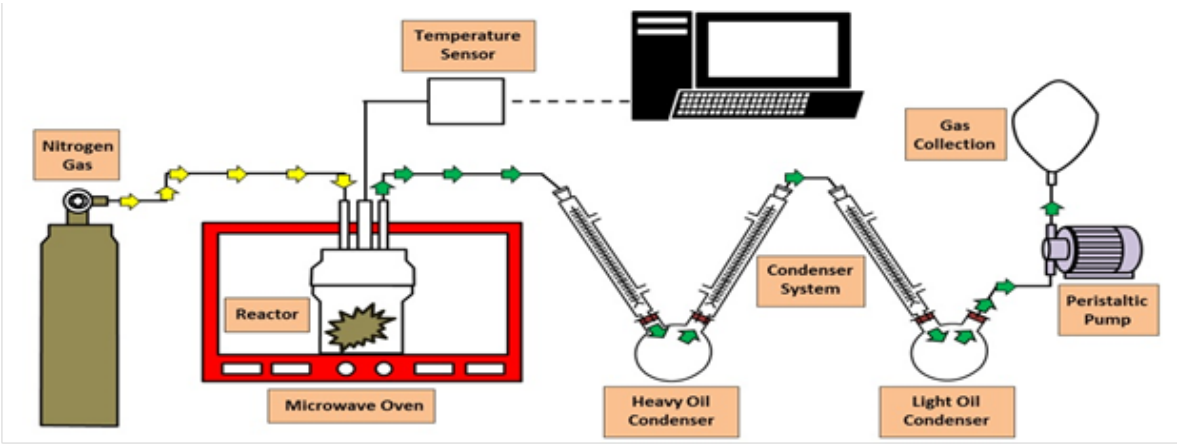


Figure 1 Microwave assisted pyrolysis equipment arrangement

Three set of condensers have been placed in series to condense the condensable gas and was collected as the liquid yields. In this research, three parameters were analyzed which are sample weight loading, microwave power level and radiation time in the range of 200g to 500g, 300W to 1000W and 10 minutes to 50 minutes respectively. Liquid products was then separated between the aqueous and liquid

oil portion by using the liquid-liquid extraction method. Hexane was used as the solvent during extraction process. The amount of liquid oil collected was used to determined the best parameter for microwave assisted pyrolysis of automotive paint sludge with the aim to achieve high liquid oil.

3.0 RESULTS AND DISCUSSION

3.1 Product Yields

From Figure 2 (a), it has been observed that at 200g of sample weight loading, liquid yields obtained almost 26.4% while for solid and gas was 8.9% and 64.7% respectively. Moreover, desired liquid product increased tremendously from 57.1g to 187.8g when sample loading was increased from 200g to 500g. The liquid product comprises of yellow liquid and a layer of dark oil. Nevertheless, liquid product obtained consists of aqueous and oil. However, insignificant liquid yields were obtained when sample loading was used less than 200g. After the liquid-liquid extraction process, it was observed from Figure 2 (b), oil content in the liquid product decreased from 200g to 500g which indicates that at 200g of sample loading gain the highest amount of oil in the liquid product at 0.1g been recovered. This is indicates that 200g of weight sample loading is a maximum weight loading for microwave assisted pyrolysis of automotive paint sludge in the designated microwave equipment that would recovered high amount of liquid oil from microwave assisted pyrolysis of automotive paint sludge.

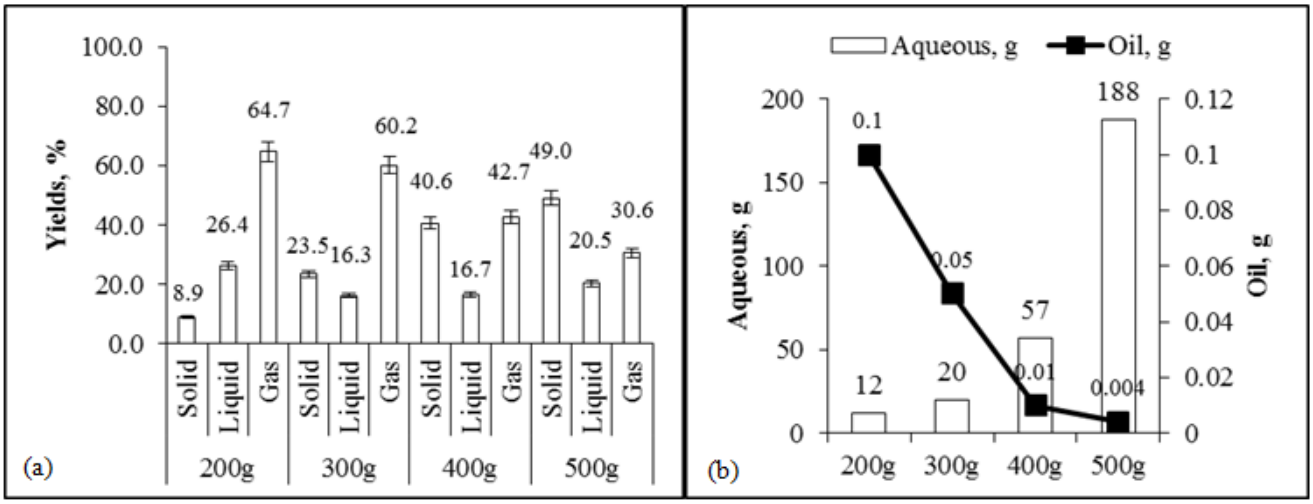


Figure 2 Product distribution and aqueous – oil yields for effect of weight loading

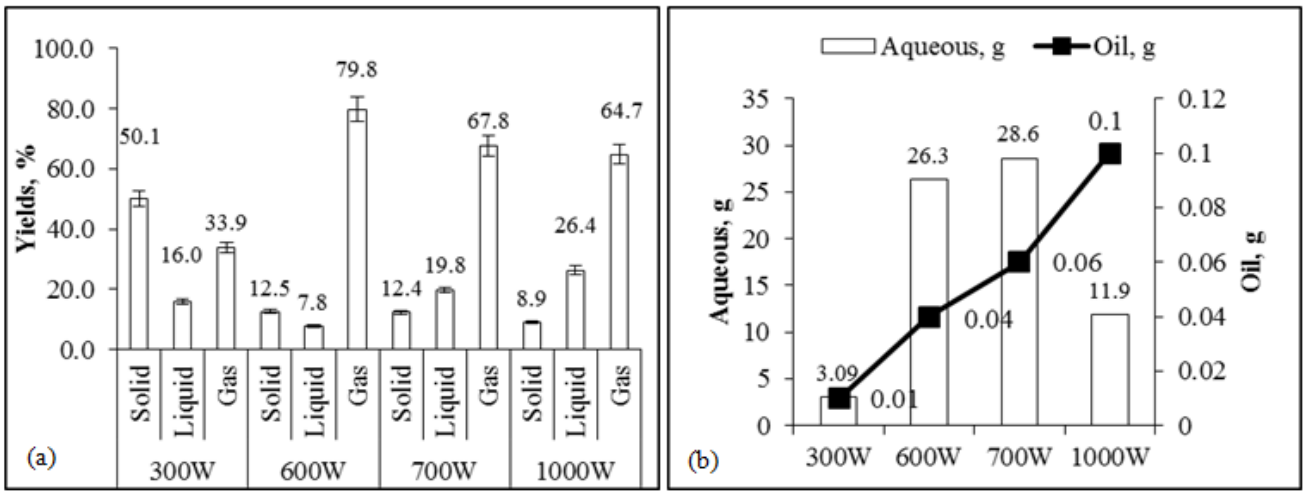


Figure 3 Product distribution and aqueous – oil yields for effect of microwave power

Furthermore, from Figure 4 (a), it was seen that 10 minutes of radiation time was not give any significant results on product yields since the there is no formation of char was spotted on the solid product. Only water was collected as the liquid product. Then, as the radiation time was increased to 20 minutes,

only dried solid residue was obtained. Besides, from Figure 4 (b), only slight formation of oil was gained and been separated at 0.05g. Solid sample is not achieved desired condition which was fully pyrolyzing the automotive paint sludge sample since no formation of char was observed. Nevertheless, first formation of char was observed at 30 minutes of radiation time with yields of solid char, liquid product and gas at 8.9%, 26.4% and 64.7% respectively. At this point, formation of oil was observed to be higher compared to 10 minutes and 20 minutes of radiation time at 0.1g or 0.05% from overall sample weight loading. As the radiation time was increased to 40 minutes and 50 minutes of radiation time, yields of solid and liquid do not give any significant changes and it also same goes to the oil yields in the liquid yields. Uniform oil yield was observed for 40 minutes and 50 minutes of radiation time at 0.08g and 0.1g respectively. It was noticed that 30 minutes of radiation time is the maximum radiation time could use in the experiment since other higher radiation times do not give any significant changes in the product yields in addition higher radiation time might increase cost of operation.

By analyzing product distribution on percentage of product, it was observed that the best operating parameter for pyrolysis of automotive paint sludge under microwave radiation was at 200g, 1000W and 30 minutes of sample weight loading, microwave power level and radiation time respectively. It was noticed that about 8.9%, 0.27%, 26.13% and 64.7% of solid char/residue, liquid oil, aqueous and gas product yields was obtained respectively. Muniz et al, 2003 [7], stated that pyrolysis of alkyd paint sludge resin obtained 30%, 34% and 36% of solid char, liquid product and gas respectively while pyrolysis of latex paint sludge obtained 25%, 56% and 19% of solid char, liquid product and gas respectively. In addition, pyrolysis of polyurethane paint sludge obtained 4%, 63% and 33% of solid char, liquid product and gas respectively.

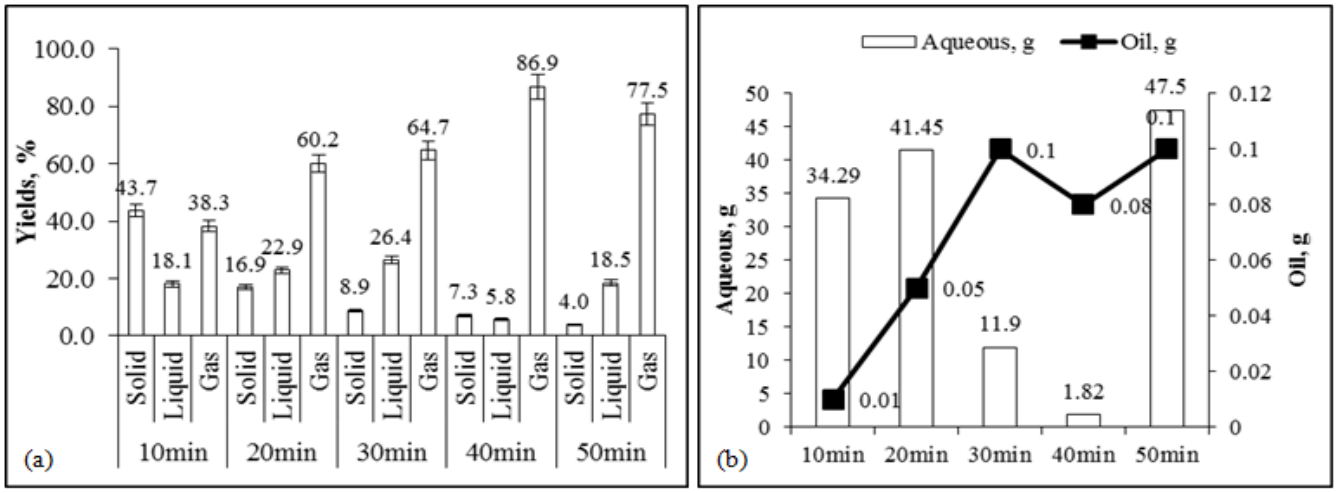


Figure 4 Product distribution and aqueous – oil for effect of radiation time

4.0 CONCLUSION

As a conclusion, it is a potential to recover the automotive paint sludge through the microwave assisted pyrolysis process due to the ability of microwave radiation that need a medium of heating. In this case, water in the automotive paint sludge plays an important role as a heating medium due its propagation with the exposure to the microwave radiation that create kinetic energy which then is converted to heat. With the modified conventional kitchen microwave oven used, it was observed that best operating parameter for pyrolysis of automotive paint sludge under microwave radiation was at 200g, 1000W and 30 minutes of sample weight loading, microwave power level and radiation time respectively, with 8.9%, 0.27%, 26.13% and 64.7% of solid char/residue, liquid oil, aqueous and gas products.

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