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Design and Fabrication of Waste Plastic Oil Converter

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***Abstract:* The study focused on the design and fabrication of a waste plastic oil converter as an effort in finding environment-friendly means of waste recycling. It is an alternative solution to increasing problem of waste disposal by converting waste plastics into a resource. Pyrolysis process was the basis in the design and fabrication of the equipment. It is a prototype/laboratory scale model that will serve as baseline in developing technology for energy recovery from waste plastics. The main components were the reactor assembly, condensing chamber, vapor line assembly, smoke cleansing unit and the waste water collecting unit. The reactor tank is made of stainless steel with holding capacity of 200g/batch of waste plastic. The equipment was tested for five trials using 200g of Type 6 plastics per trial. The temperature was controlled at 380^{0}C and operating hour of 2 hours. Test result showed that the equipment is functional with conversion efficiency (wt %) of 78.1%, waste reduction efficiency (wt %) of 94.3% and oil recovery of 883 ml oil/kg of Type 6 waste plastic.**

***Keywords:* Waste plastic oil converter, Type 6 (Polystyrene) plastic, Conversion efficiency, Waste reduction efficiency, oil recovery.**

I. INTRODUCTION

Waste management is a common problem for both developed and developing countries, because of the fact that as the population increases, the quantity of waste generated also increases. Waste collection, segregation and disposal have been a long-standing unresolved problem and will remain a problem in the future if there is no initiative made to solve it. Mismanagement of waste will result to serious environmental problems such as surface and ground water contamination, flooding, air pollution and climate change. Tanaka (2013) said that with the growing Philippine population and high economic growth expected in the coming years, the amount of solid waste to be managed is increasing on an alarming rate. Westfall M.S. and Allen N. (2004) noted that in Metro Manila alone, some 1500 tons daily is dumped illegally on private land, rivers, and creeks or openly burned, adding to heavily polluted air. Knoblauch, A. J. (2009) reported that plastic production and disposal contribute to an array of environmental problems. Chemicals added to plastics are absorbed by human bodies. Some of the compounds have been found to alter hormones or have other potential human health effects. Plastic debris, laced with chemicals and often ingested by marine animals, can injure or poison wildlife. Floating plastic wastes, which can survive for thousands of years in water, serve as mini transportation devices for invasive species, disrupting habitats. Plastic buried deep in landfills can leach harmful chemicals that spread into groundwater.

Although the impact of waste plastic to our health and environment may not always cause noticeable harm or destruction, research indicates that plastic waste in landfill and in badly managed recycling systems could be having an impact from the chemicals contained in the plastic. Plastic is generally derived from petroleum and when placed in landfills becomes carbon sink and if incinerated it increases carbon emissions.

Since incineration is less accepted and the cost of state-of-the-art landfill facility is unaffordable, finding economically feasible and environment friendly means of waste recycling and reduction is challenging. The researcher came up with the idea to design and fabricate a device that can be used in turning waste plastics into a resource. The waste plastic oil converter employs the pyrolysis method of converting waste plastics into oil. The advantage of pyrolysis over landfill and incineration is in terms of environmental protection because it reduces the risk of air, water and soil pollution. In pyrolysis, the possibility of recycling is improved, because the resulting product such as gas and liquid can be used as combustible fuel to substitute fossil fuels.

II. LITERATURE SURVEY

Harsha Vardhan Reddy T, Aman Srivastava, Vaibhav Anand and Saurabh Kumar stated in their paper entitled "Fabrication and Analysis of a Mechanical System to Convert Waste Plastic into Crude Oil" that use of plastics are increasing day by day. One of the major problems following it is the disposal of waste generated from plastics. Since plastics are made of crude oil, why can't it be reverse processed? i.e., plastics back to crude oil. This is the basic idea behind the paper. Besides helping to remove a lot of plastic waste generated thus creating a neat and tidy environment. It also helps to generate fuel which when converted to convenient form can be used as a source of energy. This combined advantage has inspired us to design and develop a machine which can efficiently convert plastic to suitable form of fuel. In this paper, a method is suggested to convert waste plastic to useful fuel. The objective of this is to develop a machine which converts plastics to some useful form of fuel.

The paper titled "Design of Viable Machine to Convert Waste Plastic into Mixed Oil for Domestic Purpose" by Yasha Shukla, Hemant Singh, Shiwangi Sonkar and Deepak Kumar states in the abstract that the aim of the article is to provide a more efficient design of machine to convert waste plastic into mixed oil for domestic purpose. In this machine daily domestic waste like polyethene, polypropylene or normal plastic carrying bag are converted to oil. This machine employs a closed container (stainless steel), temperature controlling electric heater and layers of insulating materials, these materials make machine more efficient and safer for use. For effective pyrolysis process the temperature of stainless steel container (full of waste plastics) is raised by temperature controlling electric heater and for condensation process, water at room temperature is employed. There are three outputs obtained from this machine which are mixed oil, hydrocarbon gas and carbon black charcoal. These products can solve the problem of daily domestic requirement of fuel for local villagers. This machine is only suitable for normal carrying bag of plastic and not for PET bottles or PVC pipes. The design of machine is efficient to manage daily domestic plastic waste and in return provides three types of fuel.

The paper titled "Design, Fabrication and Performance Study of a Biomass Solid Waste Pyrolysis System for Alternative Liquid Fuel Production" by Md. Akram Hossain, Md. Raquibul Hasan & Md. Rofiqul Islam, the abstract is presented here. Now-a-days production of Bio-fuel is a prime concern in the world due to decrease other fuel source. The conversion of devdaru seeds into pyrolytic oil by fixed bed reactor has been taken into consideration in this study. A fixed bed pyrolysis system has been designed and fabricated for obtaining liquid fuel from biomass solid wastes. The major components of the system are: fixed bed reactor, liquid condenser and liquid collectors. The devdaru seeds in particle form is pyrolized in an externally heated 7.6 cm diameter and 46 cm high fixed bed reactor with nitrogen as the carrier gas. The reactor is heated by means of a cylindrical biomass source heater. Rice husk, cow dung and charcoal are used as the energy source. The products are oil, char and gas. The parameters varied are reactor bed temperature, running time and feed particle size. The parameters are found to influence the product yields significantly. The maximum liquid yield is 51 wt% at 5000C for a feed size of <1.18 mm at a gas flow rate of 5 liter/min with a running time of 90 minute. The pyrolysis oil obtained at these optimum process conditions are analyzed for some of their properties as an alternative fuel. We get the higher heating value of devdaru seeds oil is 24.22 MJ/kg. The heating value of the oil is moderate.

The paper titled "Turning mixed plastic wastes into a useable liquid fuel" by S.L. Low, M.A. Connor and G.H. Covey, the abstract is presented here. As landfill and incineration become more expensive and less accepted, the recycling of plastic wastes is gaining increasing importance. More emphasis is thus being given to new disposal options, which have high energy recovery values and are more environmentally attractive. Pyrolysis is one promising method for the treatment of mixed and contaminated plastic wastes. Plastics are thermally degraded to produce useful liquid hydrocarbons, which can then either be added to existing fuel or solvent product, or returned to a refinery where they can be added to the feedstocks. A simple pyrolysis reactor system is described. Results of pyrolysis tests showed that pure samples of polyolefinic and polystyrene resin can readily be pyrolysed to produce liquid yields in excess of 70%. However, liquid yields were affected by heating rates and heat loss patterns in the reactor system. Further experimental work suggests that when pyrolysed, mixed plastic wastes behave much like the resins from which they originate. In light of the results from the experiments, the technical feasibility of setting up a pyrolysis plant in Victoria to process waste plastics into liquid fuel was discussed. This study thus forms the ground work needed for the design of a small pyrolysis plant.

III. METHODOLOGY

A. Research Procedures:

The design and fabrication of waste plastic oil converter went through a series of stages. It includes planning, designing, fabrication, preliminary testing, modification, final testing and data gathering. Thorough planning was employed in the conduct of the study to arrive at the desired output. This was done through extensive review of literature and studies on the existing practices and technology on converting waste plastic into a resource, particularly pyrolysis process. It also included the selection of materials, tools, equipment, parts and accessories for the development of waste plastic oil converter. The design of the equipment involves the electric heater that was installed with temperature controller to attain the desired temperature. It also includes the reactor tank, reactor tank frame, smoke cleansing and condensing tank and its frame. Design also covers the proper placement and arrangement of every component of the machine. Environmental aspect was also considered in the design of the machine. A smoke cleansing tank which also served as oil condensing tank was made to clean the smoke, and condense the remaining vapor before it goes to the atmosphere. Fabrication was done when all the needed materials were ready. The materials used were angle bar, stainless pipe, copper tube, hose, hose clip, air chuck, stainless steel pot, electric heater, thermocouple, temperature controller, circuit breaker, contactor, compressor, condensing tank and waste water collecting tank. Testing was done for two stages. The preliminary testing and final testing, respectively. Before the testing was made, feedstock was prepared and weighed accordingly. One thousand grams of Type 6 (Polystyrene) plastic composed mainly of disposable styro cups, plates and food boxes were cut into small pieces and divided into five samples weighing 200 grams each. Modification on some parts of the equipment was done after the preliminary testing to improve its functionability. After modifications, final testing was conducted to test the performance of the designed and fabricated waste plastic oil converter. Only the liquid product and char was collected while the gas was submerged in water before releasing it to the atmosphere. Chemical properties of the derived oil were not investigated due to the absence of laboratory facilities in the locality.

B. Testing Procedure:

Operation of the equipment needs a properly trained operator and a well-equipped facility due to the formation of highly flammable liquid. The equipment can be operated indoor provided that the area is well ventilated and the end of the exhaust stack is pointing outside the room. However, it is advised that the equipment must be used in an open area to avoid the accumulation of gas coming out of the exhaust stack. Before the operation it was made sure that the equipment is unplug from the power source. The smoke cleansing tank was remove from the frame and filled with clean water. After adding water, it was reinstalled in its frame and the waste water drain hose was connected in it. Then the reactor tank feeder cap was removed to allow the filling of the reactor tank with 200g Type 6 plastic. The reactor tank was closed after filling and the equipment was connected to 220VAC power source. The temperature controller was set to 380^0C and the circuit breaker was turned on. The equipment was run for 2 hours with 20 minutes cracking time, 2 minutes vapor residence time and 1 minute vapor evacuation time. After 2 hours, the equipment was turned off and the converted oil was collected and measured using graduated cylinder and digital weighing scale. The char or the residue inside the reactor tank was also collected and weighed accordingly. Testing was done for 5 trials to collect data for performance evaluation of the equipment.

C. Performance Evaluation Measures:

In this research, the performance of the fabricated waste plastic oil converter was evaluated in terms of conversion efficiency (wt %), waste reduction efficiency (wt %), oil recovery (ml of oil/kg of plastic) and was expressed by the following formula.

1. Conversion Efficiency (wt %)

$CE = \frac{Wo}{Wsm} x \ 100\%$

Where:

CE = Conversion Efficiency

Wo = Weight of oil converted (g)

Wsm = weight of the sample material(g)

2. Waste Reduction Efficiency (wt%)

$WRE = \frac{Wsm-Wc}{Wsm} x \ 100\%$

Where:

WRE = Waste Reduction Efficiency

Wc = Weight of char inside the reactor (g)

Wsm = weight of sample material (g)

3. Oil Recovery (ml/kg)

$OR = \frac{V}{Wsm}$

Where:

OR = Oil Recovery (ml/kg)

V = Volume of oil recovered (ml)

Wsm = Weight of sample material (kg)

IV. RESULTS AND DISCUSSIONS

A. Parts of the Waste Plastic Oil converter:

A.1 The base:

It is the main support of the equipment in which other components are placed above it. It is a table measuring 2ft (W) x 4ft (L) x 2 7/12 ft (H).

Figure 1: The Base

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A.2 Reactor assembly:

It is the main component of the equipment where the plastic was subjected to controlled temperature and turned the melted plastic into vapor. It is composed of the following parts: (a) Circuit breaker which served as the main switch of the equipment. It is used to start or stop the equipment from operating and has a 30 A capacity (b) Electric heater which served as the source of heat for melting the plastic.

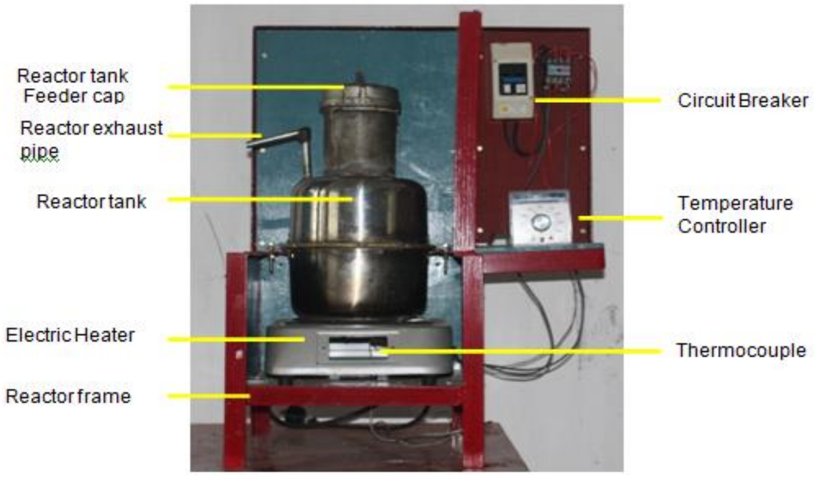

Figure 2: Reactor assembly

(c) Temperature controller is the device that controls the temperature of the electric heater. It cuts-off the supply of electricity when the desired temperature produced by the electric heater is reached and turn on the electric heater when the temperature is below the desired value (d) Thermocouple is a sensing device which detects the temperature produced by the electric heater. It is located at the bottom of the reactor tank and the other end is connected to temperature controller (e) Reactor tank is a cylindrical chamber made of stainless steel where the plastics were melted and turned to vapor. It has a feeder cap for closing and opening the reactor tank and exhaust pipe as passageway of the vapor. It has a capacity of 452.40 cu.in, the diameter is 8 inches and the height 9 inches (f) Reactor feeder cap is used for opening and closing the reactor tank (g) Reactor exhaust pipe served as the passageway of vapor coming out from the reactor tank, and (h) Reactor frame is the part where all the other parts of the assembly are attached.

A.3 Condensing Chamber Assembly:

It served as the condensing tank and collecting tank of oil and has the following parts. (a) Condensing tank/collecting tank is the part where the vapor condenses and oil is collected. It has a diameter of 3.5 inches and a height of 7 inches (b) Condensing chamber intake line served as the passageway of vapor as it enters the condensing tank (c) Condensing chamber exhaust pipe is the part where the uncondensed vapor passes through as it goes out of the condensing tank.

Figure 3: Condensing chamber assembly

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A.4 Vapor Line Assembly:

It is used to convey uncondensed vapor from the condensing chamber to the compressor and has the following components: (a) Vapor line which is made of stainless steel tube that serves as the passage way of the uncondensed vapor to flow to the compressor (b) Reactor-compressor connecting line that links the vapor line and the compressor suction line (c) connecting hose is a transparent hose that connects the reactor-compressor line with compressor suction line and the vapor line. It uses hose clip to tighten the connection and prevent leakage of vapor.

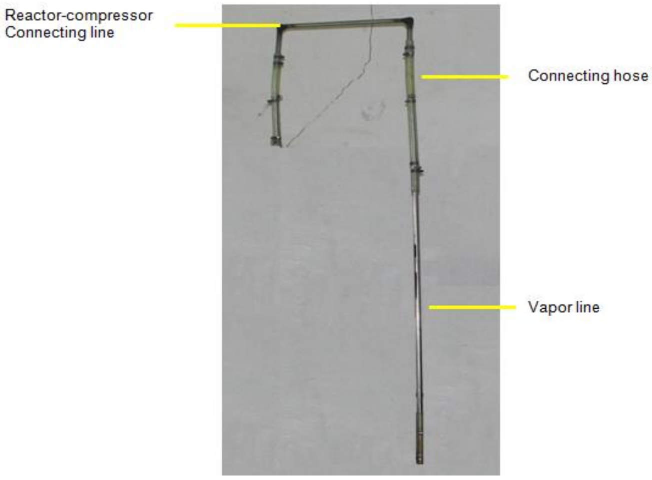

Figure 4: Vapor line assembly

A.5 Smoke cleansing unit:

The smoke cleansing unit is used to clean the smoke produced in the process of converting waste plastic into oil. It has the following parts: (a) Compressor – it suctioned the smoke or uncondensed vapor and deliver it to the smoke cleansing tank (b) Smoke cleansing tank - is made of PET plastic with a capacity of 4 gallons of water. It is in this part that the smoke is submerged into the water thereby removing ash and particulates. It also condenses the remaining vapor into oil (c) Smoke service line-serves as the passage of smoke from the compressor into the smoke cleansing tank. It is made of ¼ inch copper tube and is dipped under water inside the smoke cleansing tank (d) Connecting line-is made transparent hose that connects the smoke service flow and the compressor discharge line (e) Smoke cleansing unit frame – the part that holds all other parts of the smoke cleansing unit.

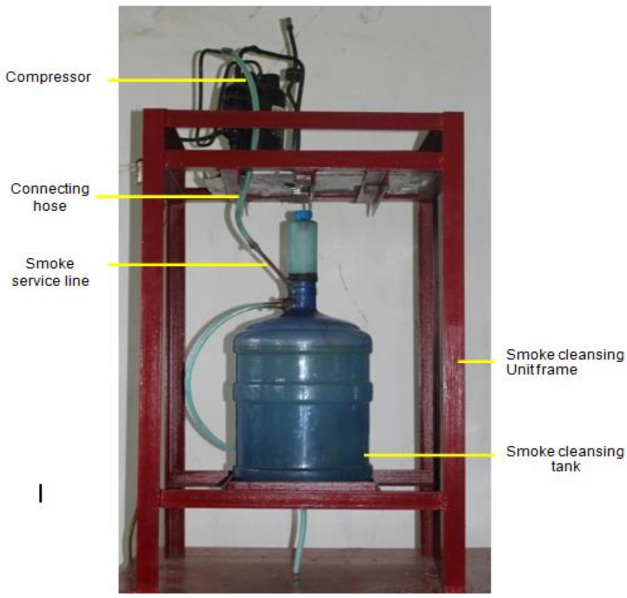

Figure 5: Smoke cleansing unit

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A.6 Waste water collecting unit:

The waste water collecting unit has transparent hose that serves as a waste water discharge line coming out of the smoke cleansing tank and a container which serves as waste water collecting tank. Waste water is disposed away from bodies of water to prevent contamination.

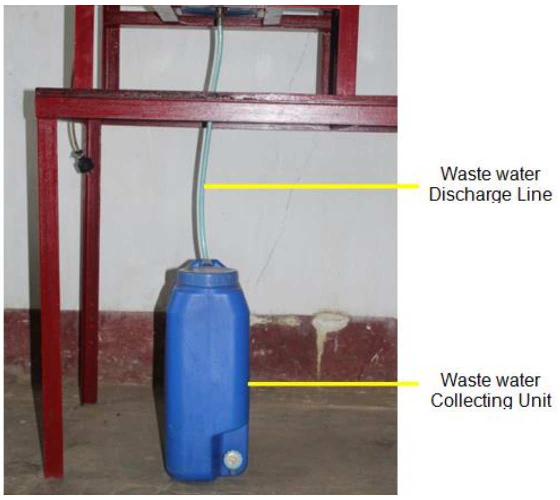

Figure 6: Waste water collecting unit

Figure 7: Set-up of the waste plastic oil converter

B. Performance Evaluation

Table 1: Data gathered during testing

Parameters	TRIAL						Average
	1	2	3	4	5	Total	
Weight of Type 6 plastic (g)	200	200	200	200	200	1000	**200g**
Duration of Operation (2 hr)	2	2	2	2	2	10	**2 hr**
Volume of oil recovered (ml)	160	164	165	176	168	833	**166.6 ml**
Weight of oil recovered (g)	146	152	152	164	154	768	**153.6 g**
Weight of char recovered (g)	13	11	12	10	11	57	**11.4 g**

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Figure 8: Oil and char as an output of the equipment

Table 2: Summary of results

Parameters		**TRIAL**					**Average**
	1	**2**	**3**	**4**	**5**	**Total**	
Conversion Efficiency (wt%)	73.0	76.0	82.5	82.0	77.0	390.5	**78.1 %**
Waste Reduction Efficiency (wt%)	93.5	94.5	94.0	95.5	94.5	471.5	**94.3 %**
Oil recovery (ml oil/kg waste plastic)	800	820	825	880	840	4165	**833 ml/kg**

Conversion efficiency is the ability of the equipment to convert waste plastic into oil in terms of weight. This is computed by dividing the weight of oil recovered by the original weight of plastic and is multiplied by 100. Based on the result of the study, the waste plastic oil converter has a 78.1% conversion efficiency.

Waste reduction efficiency is the measure of how efficient the equipment in reducing waste in terms of weight. This is calculated by subtracting the weight of char from the original weight of the plastic divided by the original weight of the plastic and is multiplied by 100. As a result of the study, the equipment showed 94.3% waste reduction efficiency.

Oil recovery is the measure of how much oil the equipment can recover per kg of waste plastic. In this study, the waste plastic oil converter was able to recover 833 ml of oil per kilogram of Type 6 waste plastics.

V. CONCLUSIONS

Based on the result of the study, the waste plastic oil converter was found to be operational and functional. Using Type 6 waste plastic as feedstock, the equipment was able to garnered considerable waste reduction efficiency and a notable conversion efficiency and oil recovery. The process was successful in converting Polystyrene plastic into oil without using catalyst. It is able to convert at an average capacity of 83.3 ml oil/hr. Although it is a prototype or laboratory scale model, it can be used to address the pressing problem of waste disposal in the country.

VI. RECOMMENDATIONS

The performance of the waste plastic oil converter is considered satisfactory. However, there is still a need to enhance its design to further improve its performance. The following recommendations are suggested:

1. Further study must be conducted on the design of the machine to increase its performance. The volume of the reactor tank should be increased to accommodate more amount of feedstock and a thicker material should be used in the fabrication of reactor to withstand a higher temperature and prolong its usability. Also, higher temperature controller should be used to increase the temperature inside the reactor.
2. Further studies can be conducted to determine the performance of the equipment using other types of waste plastic
3. Studies on the chemical properties of oil recovered from Type 6 and other types of plastic can be conducted to determine its properties and establish its potential uses or application.
4. Lastly after determining the possible uses or application of oil derived from waste plastics, upgrading and pilot testing of the equipment must be conducted to validate the economic and environmental benefits that can derived from it.

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