Generation of Transportation Fuel from Solid Municipal Waste Plastics

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ABSTRACT

Waste plastics are one of the biggest environmental concerns the world faces today. The amount of waste plastics is increasing rapidly each day. Waste plastics exposure to the environment is very hazardous. Over time waste plastics photo-degrade and become very tiny dust particles. These dust particles contain very harmful compounds including benzene, sulfur, carbon and many others. According to studies, waste plastic's components are one of the biggest reasons for the depletion of the ozone layer and contributor of global warming. Many scientists have been trying to figure out to utilize these waste plastics and convert them into useful energy source. It is possible to convert waste plastics into energy because they are made from petroleum. They have succeeded in developing many methods including pyrolysis, catalytic cracking, thermal degrading and others. Natural State Research Inc. (NSR) has been working with the thermal degradation process and was successful in extracting fuel from waste plastics at 370 – 420 degree C.

Keywords: Waste plastics, Fuel, FT-IR, Degradation, Hydrocarbon, GC/MS, Thermal, Cracking

INTRODUCTION

Plastic are macromolecules, formed by polymerization of hydrocarbon materials and it has the ability to be shaped by the application of reasonable amount of heat and pressure making them very easy to use in our daily lives. These plastics are made from crude oil a limited energy source. Plastic are being used all over the world for all sorts of activities and afterwards these plastics are becoming waste plastics. Waste plastics do not biodegrade in landfills and are not easily recycled and degrade in quality during the recycling process causing people to dump them in land fill. This method of dumping requires a lot effort and money.

Not only on land but waste plastics are causing problems in the sea region as well.
Research conducted by Charles J. Moore (Long Beach California) about the Great Pacific Garbage Patch shows the horror and impacts waste plastic can have on oceanic and marine life. According to his study the Garbage Patch is estimated to be twice the size of Texas and contains ~3.5 million tons of waste material and 80% of it is waste plastic litter [1].

Methods have been developed to utilize these waste plastics and convert them in to low cost and environmentally friendly fuels. If carried out properly this method can help save the environment and the economy. Some methods of conversion of waste plastics into fuel include pyrolysis [2-3], thermal degradation [4-6], catalytic cracking [7-8] and others. The current commercial fuel is a hazard to the environment. Emissions from evaporated fuel includes unburned hydrocarbons, which are responsible for ground-level ozone and smog; nitrogen oxides (NO_x), which contribute to ozone and acid rain; carbon monoxide (CO), a toxic byproduct of incomplete combustion and a health hazard; sulfur dioxide (SO_2), which contributes to acid rain; and carbon dioxide (CO_2), a greenhouse gas that contributes to global warming.

These fuels derived form wastes plastics are expected to be much more environmentally friendly than the conventional fuels and since the raw resource of waste plastics are seemingly unlimited, the production of the fuel will be relatively less.

Natural State Research Inc. (NSR) has developed such method where the waste plastics are collected from various supermarkets and other places and convert them into liquid hydrocarbon fuels.

PROCESS DESCRIPTION

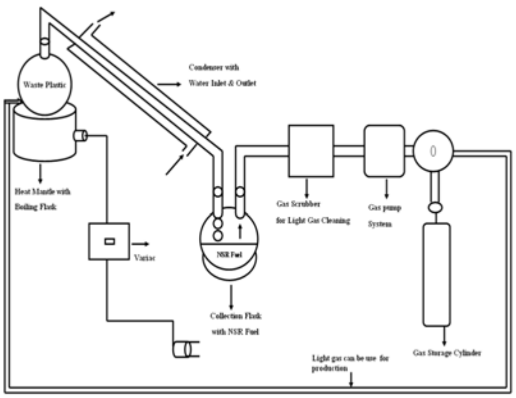

Figure 1: NSR fuel production process

NSR discovered a process that uses thermal degradation to heat the waste plastic to form liquid slurry; at a temperature ranging from 370 – 420 ^{0}C with catalyst, then the liquid slurry turns into vapor, that vapor is then condensed (***see figure 1***) to produce the liquid hydrocarbon fuels titled NSR Fuel. It should be noted that no chemicals are used to carry out this process and the end product is filtered using a commercial fuel purifier that operate using coalescence and centrifugal force. During the process some valuable light gas is produced. That gas is cleaned using a gas scrubber and collected using a pump and storage gas cylinder. This light gas can be used to heat the plastics to produce fuel saving cost for fuel production.

Experiments in a lab scale have been performed with majority of the waste plastic types: high density polyethylene (HDPE, code 2), low density polyethylene (LDPE, code 4), polypropylene (PP, code 5), and polystyrene (PS, code 6). These plastic types were investigated singly and in combination with each other. In a laboratory scale, the weight of a single batch of input plastic for the fuel production process ranges from 250 grams to 4 kilograms. The waste plastics are collected, optionally sorted, cleaned of contamination or without cleaning and grinded into small pieces prior to the thermal liquefaction process. The produced fuel has density of 0.77 g/ml. With 1 kilogram (kg) of waste plastic about 1200 – 1300 ml of NSR fuel can be produced. Also producing 1 gallon of fuel requires 12-13 kWh which is about $1.32 in laboratory scale. When fully commercialized the production amount will increase and the cost will decrease half. The end products consist of 90% of liquid hydrocarbon fuel 5% light gas (C1-C4) (Methane, Ethane, Propane and Butane) and 5% solid residue.

Sample Name	Inflection Point in Temperature (º C)	On Set Temperature (º C)
LDPE 4	466.16	436.23
HDPE 2	477.96	450.40
PS 6	364.88	326.62
PP 5	403.72	359.63

Table 2: Thermo-gravimetric Analysis (TGA) Results of Waste Plastic Samples

Plastic Name	Density g/cm^3
LDPE 4	0.92-0.94
HDPE 2	0.95-0.97
PP 5	0.90-0.91
PS 6	1.05-1.07

Table 3: Physical properties of virgin plastics

Plastic Name	Melting Point (º C)
LDPE 4	120
HDPE 2	130
PP 5	160
PS 6	240

Table 4: Melting points of virgin plastics

FUEL ANALYSIS

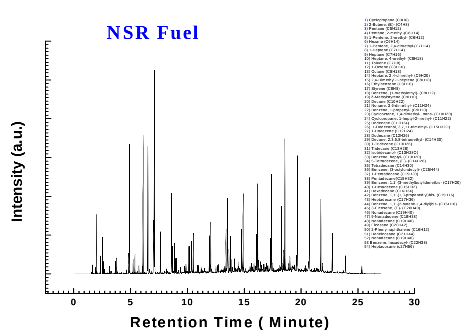

Figure 5: Gas Chromatogram of NSR Fuel

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The NSR fuel carbon c hain ra nges from (C3-C27). T hese data indicates that the NSR fuels have a wi de ra nge of hydrocarbon g roups resulting in a h igher th ermal co ntent. Th e thermal content allows the fuel to burn for longer period of time resulting in efficiency when used in compatible engines.

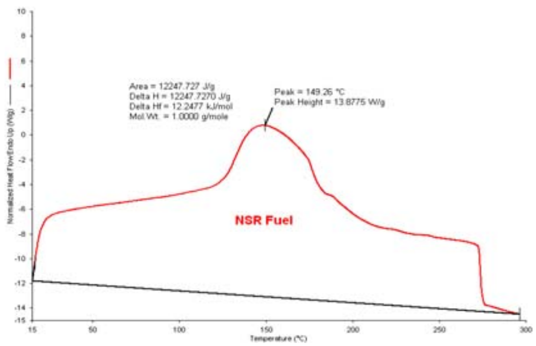

Figure 6: Differential Scan ning Calorimeter (DSC) graph of NSR Fu el indicating the boiling point

The DSC graph indicates the peak boiling point a substance c an reach. In this case the NSR fuel has a p eak b oiling point of 149.26 ^{0}C an d a Delta H value of 1 2247.7270 j/g. that indicates the enthalpy value of the fuel.

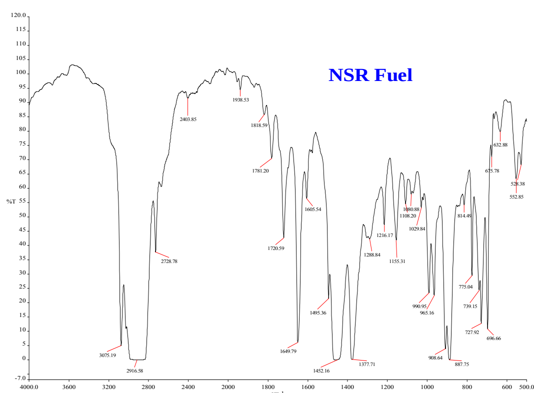

Figure 7: FT-IR spectra of NSR Fuel

The c ompounds present i n the NSR fuel a re as follows: H Bonded NH, CH2 , C- CH3,Non Conjugated, Non C onjugated, Am ides, C H_2, Acetates, -C H= CH $_2$, -CH=CH-, C= CH_2, -CH=CH- (cis).

Figure 8: FT-IR library search compound list

Elemental Analyzer (E A-2400) result under CHNS m ode indicates that NSR fuel contains 85.61 % car bon, 13.10% Hy drogen, 0.3 % Nitrogen and 2.26% Sulfur.

Sample Property	Test Method	Result
Gross Heat of Combustion (BTU)	ASTM-D240 12	7,413 BTU/gal
API Gravity	ASTM-D4052	
Barometric pressure	ASTM-D86	760 mm Hg
IBP recovery	ASTM-D86	109.5 ºF
10% recovery	ASTM-D86 24	6.2 ºF
50% recovery	ASTM-D86 48	7.0 ºF
FBP recovery	ASTM-D86 63	3.5 ºF
Residue ASTM	-D86	28.2 Vol%
Corrected loss	ASTM-D86 1.	2 Vol%
Corrected Recovery	ASTM-D86 70	.6 Vol%
Pour Point	ASTM-D97	9 ºC
Cloud Point	ASTM-D2500	12 ºC
Freezing Point	ASTM-D2386 1	2.0 ºC
Conductivity A	STM-D2624	2 pS/M
Sulfur Content	ASTM-D5453 2	.8 mg/kg
ASTM Color	ASTM-D1500	1.5
Water Content – Karl Fischer	ASTM-E203 37	mg/kg
Vanadium content	ASTM-D5708 <1	.00 mg/kg
Nickel content	ASTM-D5708 <1	.00 mg/kg
Iron content	ASTM-5708	2.70 mg/kg
Ash C ontent	ASTM-D482	0.001 Wt %

@ 775 ºC		
Flash Point-PMCC (procedure A)	ASTM-D93	< room temp ºF
Carbon Residue (MCRT)	ASTM-D4530	< 0.10 Wt %
Acid Number of Petroleum Products	ASTM-D664	0.10 mg KOH/g

Table 9: INTERTEK third party report of analysis of the NSR Fuel

CONCLUSION

The final NSR product is tested and proven to be compatible with all types' internal combustion engines. Also when used with suitable generators it can produce electricity to power all sorts of appliances. The NSR fuel is to be tested under all the ASTM standard test and further modification are subjected to be conducted in the future.

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