

# 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 face 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 degradation 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].

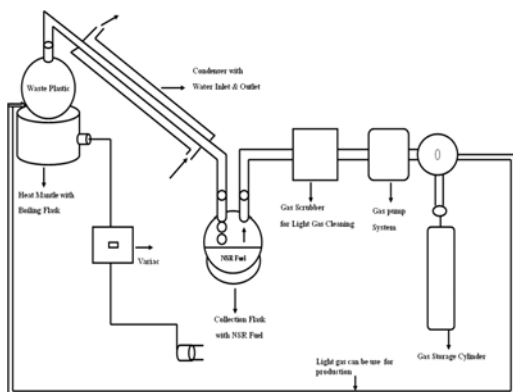
Methods have been developed to utilize these waste plastics and convert them into low cost and environmentally friendly fuels. If carried out properly this method can help save the environment and the economy. Some methods of conversion of waste plastics into fuel include pyrolysis [2-3], thermal degradation [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<sub>x</sub>), which contribute to ozone and acid rain; carbon monoxide (CO), a toxic byproduct of incomplete combustion and a health hazard; sulfur dioxide (SO<sub>2</sub>), which contributes to acid rain; and carbon dioxide (CO<sub>2</sub>), a greenhouse gas that contributes to global warming.

These fuels derived from waste 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 °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 (° C) | On Set Temperature (° 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

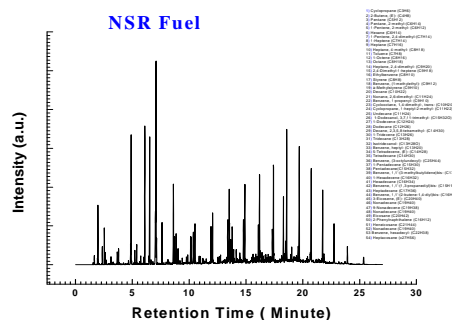
| Plastic Name | Density g/cm <sup>3</sup> |
|--------------|---------------------------|
| LDPE 4       | 0.92-0.94                 |
| HDPE 2       | 0.95-0.97                 |
| PP 5         | 0.90-0.91                 |
| PS 6         | 1.05-1.07                 |

**Table 3:** Physical properties of virgin plastics

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

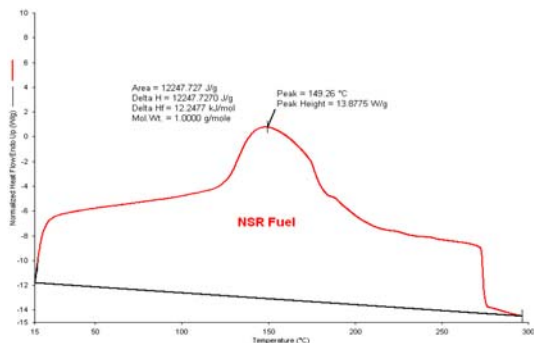
**Table 4:** Melting points of virgin plastics

## FUEL ANALYSIS



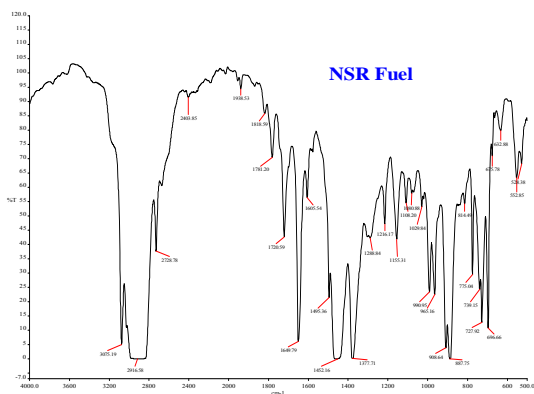
**Figure 5:** Gas Chromatogram of NSR Fuel

The NSR fuel carbon chain ranges from (C3-C27). These data indicates that the NSR fuels have a wide range of hydrocarbon groups resulting in a higher thermal content. The thermal content allows the fuel to burn for longer period of time resulting in efficiency when used in compatible engines.



**Figure 6:** Differential Scanning Calorimeter (DSC) graph of NSR Fuel indicating the boiling point

The DSC graph indicates the peak boiling point a substance can reach. In this case the NSR fuel has a peak boiling point of 149.26 °C and a Delta H value of 12247.7270 j/g. that indicates the enthalpy value of the fuel.



**Figure 7:** FT-IR spectra of NSR Fuel

The compounds present in the NSR fuel are as follows: H Bonded NH, CH2, C- CH3, Non Conjugated, Non C onjugated, Amides, C H<sub>2</sub>, Acetates, -C H=CH<sub>2</sub>, -CH=CH-, C= CH<sub>2</sub>, -CH=CH- (cis).

FT-IR Library Search Compound List

| Library Name | Compound Name | Library Path |
|--------------|---------------|--------------|
| Library 1    | Compound 1    | Path 1       |
| Library 2    | Compound 2    | Path 2       |
| Library 3    | Compound 3    | Path 3       |
| Library 4    | Compound 4    | Path 4       |
| Library 5    | Compound 5    | Path 5       |
| Library 6    | Compound 6    | Path 6       |
| Library 7    | Compound 7    | Path 7       |
| Library 8    | Compound 8    | Path 8       |
| Library 9    | Compound 9    | Path 9       |
| Library 10   | Compound 10   | Path 10      |
| Library 11   | Compound 11   | Path 11      |
| Library 12   | Compound 12   | Path 12      |
| Library 13   | Compound 13   | Path 13      |
| Library 14   | Compound 14   | Path 14      |
| Library 15   | Compound 15   | Path 15      |
| Library 16   | Compound 16   | Path 16      |
| Library 17   | Compound 17   | Path 17      |
| Library 18   | Compound 18   | Path 18      |
| Library 19   | Compound 19   | Path 19      |
| Library 20   | Compound 20   | Path 20      |

**Figure 8:** FT-IR library search compound list

Elemental Analyzer (E A-2400) result under CHNS mode indicates that NSR fuel contains 85.61 % carbon, 13.10% Hydrogen, 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 °F      |
| 10% recovery                   | ASTM-D86 24  | 6.2 °F        |
| 50% recovery                   | ASTM-D86 48  | 7.0 °F        |
| FBP recovery                   | ASTM-D86 63  | 3.5 °F        |
| 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 °C          |
| Cloud Point                    | ASTM-D2500   | 12 °C         |
| Freezing Point                 | ASTM-D2386   | 2.0 °C        |
| Conductivity A                 | ASTM-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 Content                    | ASTM-D482    | 0.001 Wt %    |

| @ 775 °C                          |              |                |
|-----------------------------------|--------------|----------------|
| Flash Point-PMCC (procedure A)    | ASTM-D93     | < room temp °F |
| 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 of 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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