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Fuels from Municipal Solid Waste: Case Study

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Abstract

Novel methods for plastic disposal have always been warranted since the realization of plastics' threat to the environment. Taking process as the initial point, this paper concentrates on decentralizing the waste management process by providing a self sustained colony model by the POLYCRACK process. A detailed design and energy calculations for a novel reactor are presented which would take MSW as the raw material and produce various grades petro fuels as an end products. Finally, economics of the novel reactor are included along with the payback period and hence, providing a complete solution package for the long prevailing problem to be tackled at the grass root level.

Index Terms – municipal solid waste, fuel, pyro-catalysis, POLYCRACK process, waste to energy.

Introduction

The conversion of Waste to Energy has been a topic of global concern. STEPS Ltd., an Indian company based in Mumbai, Maharashtra has developed the POLYCRACK process to convert waste plastics to fuels. This technology uses the process of pyro-catalysis and is based on the principle of degradation of polymers into middle distillates to form liquid fuels. The catalyst (under patent process) selectively cuts the long chain polymer to form smaller middle length distillates. The byproduct of this process is a combustible gas which can be used as a gaseous fuel. Also, a solid free flowing carbon residue is generated which serves as a solid fuel.[1]

The whole system operates at a process temperature of 190-400^{o}C and at atmospheric pressure. The process doesn't require nitrogen purging and the reactor accepts all varieties of feed including all types of plastics, organic matter, biomedical waste, automobile fluff and refinery waste. The catalyst forms a consumable system and can be disposed off at the landfill after it saturates as a completely non-hazardous substance.[2]

Proposed Model

Considering the Polycrack process described above we expand the technology and employ it to design a novel reactor which would be installed in a housing colony. This reactor should be fed with garbage collected from the housing colony. It will provide fuels which can be used for heat and electricity generation purposes in the colony.

The aims which we are trying to fulfill by this novel reactor are:

- To reduce the cost of transportation of solid waste from housing colonies to landfills.
- To mitigate the energy consumption generally utilised for solid waste management by acting at the consumer level.
- To decrease the garbage load on landfills and hence provide more space for inhabitation.
- To reduce the consumption of fossil fuel by providing an alternate source of energy.

Design of Equipment

Initial Consideration

An experiment have been carried out to determine the following:

- Amount of waste generated per person
- Composition of the waste
- Density of MSW
- Volume of the reactor

Considered building (Sai Shakti, Goregaon (E) and Mumbai) is one with 5 floors, 3 flats per floor and 3 people per flat.

The experiment was carried out for 7 days. The garbage collected was segregated into plastic, paper, organics and other materials (glass, textiles, ceramics etc.).(table-1) The segregated garbage was dried under the sun and then moisture content was determined.

Observations

Waste generated per person = 0.2 kg
Capacity of reactor = 5*3*3*0.2 = 9.5 kg
Approximately 10 kg reactor capacity taken.

The observations made over a period of seven days The properties are reported in table –II.

Table -1Garbage collection

DAY	Paper (kg)	Plastic (kg)	Organic (kg)	Others (kg)	Moisture (kg)
1	0.38	0.75	3.75	0.51	1.39
2	0.24	0.73	3.6	0.12	1.41
3	0.33	0.48	2.67	0.35	1.18
4	0.42	0.8	2.02	0.12	0.85
5	0.3	0.66	2.88	0.35	1.29
6	0.32	0.5	2.66	0.1	1.07
7	0.47	0.78	3.59	0.15	1.29

Average of week:

1. Moisture content : 22.2%
2. Paper : 6.5%
3. Plastic : 12.3%
4. Organics : 54.6%
5. Others (Metals, Ceramics & Textiles) : 4.3%

The density of MSW was found to be 450 kg/m^3
Volume based only on the amount of MSW
= mass of MSW/average density of MSW
= 10/445 = 22.48 lit

Dimensions of Reactor

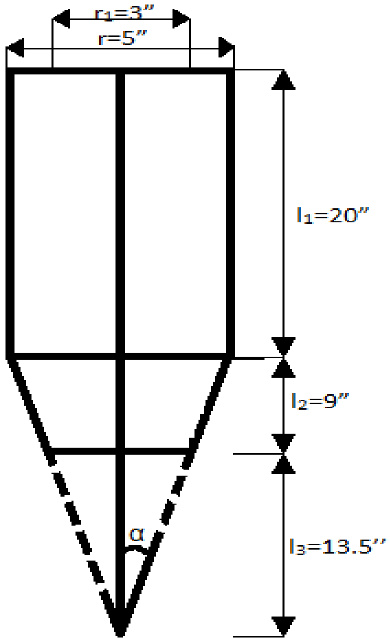
Assumption: All the MSW is stored in the cylindrical section
MOC for reactor is taken as SS 304 after various considerations.
Thus volume of reactor = volume of cylindrical section
$22.472 \times 10^{-3}\ m^3 = \pi r^2 l_1$
For a reactor, length: diameter = 2:1 usually
So, $l_1 = 4r$
Further calculations give the result,
l_1 = 19.12”

Since all the MSW fills up the cylindrical section, some volume must be allotted for the vapors which get generated in the course of the reaction. So different iterations of the multiples of initial volume are taken to accommodate for the vapors e.g. - 0.5V, 0.33V etc. And these volumes are equated to the volume of the conical section.

Also various l_3:l_2 ratios are taken into account and r_1 and α (angle of conical section) are calculated.

Small r_1 restricts manual cleaning operation. Also a smaller radius requires a longer length for the same volume and thus as length increases, the surface area which requires heating also increases and more power consumption occurs.

The value of d_1 should be minimum 6” so as to take care of the above mentioned points.



Final values calculated are:
r=5”
r_1=3”
l_1=20”
l_2=9”
$\alpha = 12.53^0 = 13^0$
Total Volume = 29.89 litres = 30 litres

Table –II: Component properties

Component	Weight (Kg)	Cp (kJ/Kg.K)	Boiling Point (^{0}C)
Paper	0.654	1.336	
Moisture	2.206	4.2	100
Plastic	1.238	1.67	260
Organic	5.46	1.55	
Other	0.431	0.65	

3.4 Power Requirement for Heating of Reactor
Taking ambient temperature as 25 ^{O}C

Assumptions:

- Melting point of PET i.e. 260 ^oC is taken as the melting for plastics.
- The Cp for other materials is taken as an average of ceramics and metals.
- Since paper is organic in nature its Cp is approximated as that of organics.
- The Specific heat for cellulose is taken as the specific heat of organic.

Based on above values total heat load was calculated to be = 3.955 kWh ------------ (A)
For 4 hours operation time
= 3.955/4
= 0.98kW

3.5 Other Dimensions of Reactor
Surface Area
Surface Area of the Reactor (S.A.) of the reactor on design basis = 0.13 sq. m

Thickness
For 5mm thickness (t):
Volume of reactor = S.A * t
Calculated sensible heat for metal = 1.175 kWh

Total heat required for the material = 3.9kWh (from A)
Net heat requirement = 5.13 kWh
For 4 hrs. operation time,
Power required per hour = 1.28 kW
Calculation of Watt density:
Watt density = Power required / Surface area
= 1.48 W/ sq. inch
For SS 304, the maximum watt density for a temperature of around 450 ^oC is 20-30 W/sq. inch. So the initial assumption of thickness of 5mm is accurate.
Taking into account 90% efficiency of power supply thickness of the reactor is recalculated as
t= 6.17 mm.

3.6 Final Specifications for the Novel Reactor
Thickness = 6mm
Surface area = 0.13 m^2
Total Heat Requirement = 5.13 kWh
Total Volume = 30 lit
r = 5”
r_1 = 3”
l_1 = 20”
l_2 = 9”

Economic analysis

We performed an economic feasibility study to evaluate the fiscal profitability of the proposed model.

Table –III. Equipment cost

Equipment	Cost(Rs)
Reactor(only raw material)	7,020
Stand	3,000
Process Control Panel	7,000
Control Panel Wiring	2,000
Gas Fired Generator	50,000
Condenser	10,000
Catalyst Cartridge	1,200
Pump for Condenser	1,500
Heating System	18,000
Insulation Cost	2,500
Accessories (nuts, bolts etc.) MOC-MS	1,000
Overall piping	2,000
Basic Cost	1,05,220

Manufacturing of the reactor will take 3 persons time of 8 working days of 8 hour shifts.

Fabrication Cost = Rs (300*3*8) = Rs 7,200

Fixed Capital Investment = (Basic + Fabrication) Cost
= Rs 1, 12,420

TAXES

Taxes are calculated on the Basic Cost

Excise Duty = 12.36% of Basic Cost
= Rs 13,895

Sales tax = 12.5% of (Basic Cost + Excise Duty)
= Rs 15,789

Octroi = 5% of (Basic Cost + Excise Duty + Sales Tax)
=Rs 7,105

Total taxes = Excise Duty + Sales Tax + Octroi
= Rs 36,789

Transportation Cost = Rs 2,500

Packaging, Forwarding and Unloading cost = Rs 600.

Operating Cost per Day (for 3 shifts)

Table-IV

Electricity (for heating and condensing)	Rs 98
Cost of Manpower	Rs 30
Catalyst Cost	Rs 143
Total Annual Cost for 300 days	Rs 81,097

Table-V Total capital investment

Item	Cost(Rs)
Fixed Capital Investment	11,2420
Taxes	36,789
Transportation Cost	2,500
Packing,Forwarding,Unloading Cost	600
Total Annual Operating Cost	81,097
Total Capital Investment	2,33,407

Product Value (per day for 3 hours shift) Solid Carbon	Rs 60
Liquid Oil	Rs 105
Gaseous Product	Rs 150
Total Annual Product Value for 300 days	Rs 94,428

Gross Profit = Operating cost - Product Value
= Rs 13,330
Since profit is non-taxable Net Profit = Gross Profit
Depreciation = 20% of Total Capital investment
= Rs 46,681
Payback Period = Fixed Capital investment/ (Gross Profit + Depreciation)
= 1.87 yrs = 23 months approx.

Discussions

The amount of garbage collected are shown in table-I. Table –II shows the properties of components. The equipment cost in detail are shown in table-III .The operating cost are shown in table-IV.and total capital investment are shown in table –V. The payback period, which is calculated is 23 months .

RESULTS:-

Fixed Capital investment = Rs 1, 12,420
Total Capital investment =Rs 2, 33,407
Gross Profit = Rs 13,331
Depreciation = Rs. 46,681
Payback Period = 1.87 yrs = 23 months approx.

Conclusion

Due to the inefficient system of solid waste management prevailing in India, the need for an alternate process is desperately needed. This design based on POLYCRACK process has a wide range of applications, right from industrial level to its main usage aim in housing societies. This novel model has been proposed incorporating green ideologies along with generating a new source of energy at the grass root level of waste generation. Its foremost and most vital advantage is that it can handle the plastic component of MSW as opposed to other methods as well as generate fuel in an eco-friendly manner. Hopefully, its compact design and optimum payback period will help to achieve the small aim of making a difference at the consumer level in near future.

Acknowledgment

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