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Effective Plastic Waste Management and Oil Production by Using Pyrolysis Process for Islampur City: A Review

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A B S T R A C T

In today's scenario, plastic waste treatment is a major concern faced by Islampur city. The waste collected and dumped on duping yards leads to various environmental issues. By experimental analysis, in a dry waste sample of 600-gram, 22% plastic was found which is a significant size. Hence, there is scope for reclaims as Refused Derived Fuel (RDF). RDF is fuel obtained from waste by the pyrolysis process. Pyrolysis is the process adopted for the combustion of plastic waste in a controlled environment. This review addresses the suitability of the project, pyrolysis viability with or without catalysts, reactors, product yield, and positive effects on the environment and society. The purpose of the paper is to find suitability for Islampur city.

Keywords: Refused Derived fuel (RDF), Plastic Waste, Pyrolysis

1. Introduction

Plastic is the product of the highest demand in every sector of human life. It is a product obtained by crude oil possessing polymeric properties. Dumping grounds are filled at a higher rate by plastic waste. Over the worldwide 10-12% plastic only recycled which is the very lesser amount. Narindar Singh (2017), plastic disposal is a major concern in many countries because of its enduring life. It majorly impacts environment balance and major threat to aquatic and terrestrial animals. environment. There is 3R's policy (i.e., reduce, reuse, recycle) which is adopted worldwide. The policy aims to minimize the amount of generation through "REDUCE" use of plastic and minimize the production at the source, "REUSE" again for the same or other purposes, and "RECYCLE" for producing new potential products. But it is not satisfactory for the wholesome elimination of plastic. There is a need of adopting various technologies for disposal.

Richard C. Thompson (2009), in that paper impacts of plastic on the environment and humans described at global level with current and future consequences. They stated that the consumption of plastic after the initial century of the plastic invention is now approaching to produce in 10 years. At the global level, it is seen that the living standards of people and the development of regions are the factors influencing on demand for plastic which is increasing day by day. On the other hand, its waste generation rate is also increasing. But there is a lack of effective disposal treatment. As it has popularity in every sector, may contribute to the development of technologies but due to inefficient disposal, serious hazards occurred to humans as well as the environment. CO2 emission goes on increasing. Humans, aquatic as well as wildlife are also influenced due to pollution arising. There are several technologies arising need is to implement efficiently.

As per Central Pollution Control Board (CPCB) 2019-20 report, Maharashtra produces 13% of plastic waste out of total waste. Plastic generated is 3800 gm per capita per year (10.41 gram per capita per day) in Maharashtra. As per the report, plastic waste generated per capita is doubled over the last five years. Islampur City is an under-development city with a 69,743 population (according to 2011census). On that behalf total plastic generated in Islampur is 0.73 tonnes per capita per day in the year 2019-20. Currently, in Islampur, plastic waste is not disposed of after collection it is

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dumped over the dumping ground.

According to P. Singh (2019), waste generation will increase with a highly increased rate of population. Incineration, mechanical grinding, and landfilling are the methods traditionally used for plastic disposal. Incineration involves the heating of plastic resulting in the emission of toxic gases like greenhouse gases. Mechanical grinding is for size reduction of plastic to obtain granules but it is not preferable for every type of plastic and is costlier. Incineration is thermal treatment given to the plastic resulting in air pollution. All concluded as newer technologies are required for the effective disposal of waste. Disposal practices should have international guidelines. As per Ramali Tahir (2019), pyrolysis is a chemical process that is economical and efficient for obtaining fuel contain in it. It is an anaerobic process. In that plastic is heated at high temperatures (450-800 oC) with catalyst. The final products obtained are fuel, char, ash, etc. Obtained fuel can't be directly used but further purification can give diesel form of fuel.

2. Need of Solid Waste Management

Environmental apprehension caused by insufficient waste management as well as the steps to contest global warming encourages actions toward sustainable management of the organic part of the waste. Unified waste management syndicates a variety of strategies for both waste management and waste reduction. Solid waste management is an issue becoming issue getting severe with increasing population and plastic waste consumption. Plastic is a wide range of synthetic or semi-synthetic organic solid materials. Plastics are typically polymers of high molecular weight.

As per Akhilesh Kumar (2020), in India, approximately 143,449 MT/day of MSW is being produced. 111,000 Metric tonnes were collected by municipalities and nearly 35,602 Metric tonnes are disposed of. Municipalities are unaware of the potential of waste. As waste collected from sources is unsegregated creates challenges due to its tremendous amount. Due to improper quantity and quality of solid waste infrastructure. Indian waste composition is somewhat different from others. Many the municipalities implement composting and biogas plants effectively from wet waste. For better recycling and to ensure the end up of landfill sites advanced treatment technologies require gasification and pyrolysis are required which are economical and environment friendly to achieve tangible municipal solid waste management.

V.R. Sankar Cheela's (2021), study recognizes scientific waste classification, public-private partnerships, systems engineering claims for decision making, and the improvement of an indicator-based performance index as indicating pathways for fast-tracking the evolution towards the development of integrated waste systems. The relationship between the identified pathway in the analytical framework for integrated waste systems development can be further investigated by integrating field investigations and systems modeling.

3. Problem Statement

From the analysis of the research paper, it is seen that refused-derived fuel can be obtained from plastic waste. Catalytic pyrolysis is the best method for better product yield. Municipal solid waste is an abundant source of plastic waste. Pyrolysis oil has impurities but can be used as diesel fuel. Further purification may enhance its property. The project scope is to design refused derived fuel system from plastic waste for Islampur City. The need of the hour is to have an efficient and long-term disposal system for thousands of tonnes of plastic dumped on dumping grounds over the last 4 years.

4. Need of Solid Waste Management for Islampur City

In India, the first plastic to diesel conversion plant was set up in Mathura, Uttar Pradesh on 2nd October 2019. The plant is working on Public-Private-Partnership (PPP). The plant can convert 1-tonne plastic waste into 150-200 liters of diesel which is sold at Rs. 45-50 per liter which is 50% cheaper than natural ones. Islampur city is a growing city with a great increasing rate of population, generates total waste of 15tonnes per day that 1.5tonnes is plastic waste. Islampur city has a solid waste plant near Islampur-Junekhed Road, Taluka Walwa, District Sangli, Maharashtra, India. The plant has an area of 16 acres. Due to some of the reasons disposal of waste is not happening and nearly 15acres of land filled with the waste since last 4 years or even before that composting of wet waste is only done. There are several heaps of waste dumped on-site without any treatment. Data was obtained from municipal authority and solid waste plant operator on 20th February 2022. To, overcome the problem and achieve environmental sustainability, the necessity of the proposed work. The plant is surrounded by an agricultural area out of the city. Dumping of waste suffered by the environment.

5. Methods and Process Available

The production of fuel in the form of RDF is demanding technology throughout India. Pyrolysis is combustion of plastic waste adopted for oil extraction. Discussed in brief below:

5.1.1. Pyrolysis:

S. D. A. Sharuddin (2017), According the author, for plastic disposal most researchers adopt the pyrolysis process for thermal decomposition of the plastic. This process is potentially treasured for obtaining products like liquid oil, gaseous, and char. This method is environmentally friendly, lesser landfills are required; valuable oil is generated which can resolve the growing demand for fuel. Kuen-Song Lin, H. (1999), In this paper author investigated that Refuse-derived fuel RDF was mechanically separated from municipal solid waste (MSW). Pyrolysis of the RDF produced approximately 28% of oils, 30% of non-condensable hydrocarbon gases, and 42% of solid residues at 773 K. Experimentally, pyrolysis of RDF generated approximately 28% of oils and 30% of non-condensable hydrocarbon gases and 42% of solid residues at 773 K.

5.1.2. Analysis of Plastic for Pyrolysis Process:

Municipal waste is collected by governing authorities and contains a mixed type of plastic having several types: Polyethylene terephthalate (PET) – includes soft drink bottles, mineral water bottles, fruit juice containers, cooking oil containers, etc. High-Density Polyethylene (HDPE) – includes milk jugs, cleaning agent containers, laundry detergent containers, shampoo bottles, etc. Polyvinyl Chloride (PVC) – includes trays for sweets, and fruits, plastic packing (bubble foil) and food foils to wrap the foodstuffs. Low-density polyethylene (LDPE)- includes crushed bottles, shopping bags, highly resistant sacks, most of the wrappings, etc. Polypropylene (PP)- includes furniture, toys, lining, and external borders of cars. Polystyrene (PS)- includes hard packing, refrigerator trays, cosmetic bags, CD cases, and vending cups. Other plastic includes acrylic, polycarbonate, polylactic fibers, nylon, fiberglass, etc. Based on this classification, researchers carried out their work and gave results. Rashid Miandad (2019), in this paper author, experimented with pyrolysis by considering types of plastic while maintaining the same quantity of sample, temperature, and NZ catalyst. Groups of samples with concentration are PE (100%), PS (100%), PP (100%), PS/PE (50-50%), PS/PP (50-50%), PP/PE (50-50%), PS/PP/PE (50-25-25%), PS/PE/PP/PET (40-20-20-20%). According to them, the catalytic process gives the best result. Oil yield for PS (70-60%), PP (40-54%), PE (40-24%). PE/PP/PS gives oil yield (44-40%) while PE/PS/PP/PET (28-30%) gives the least result.

5.1.3. Types Of Pyrolysis Process:

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5.1.4. Types of Pyrolysis Process:

The pyrolysis can be done by thermogravimetric method or by catalytic pyrolysis. Thermogravimetric pyrolysis is the heating of plastic waste at higher temperatures whereas, in catalytic pyrolysis, plastic is heated with another catalyst like zeolite.Bhargav Baruah (2020)**,** the author found that high-pressure thermogravimetric pyrolysis resulted in higher vapor formation temperature and also an increase in pyrolysis pressure. The C_2-C_4 gases are immensely evolved with an increase in temperatures. This indicated that the conditions of high pressure and high temperature lead to in situ thermal cracking and reforming, resulting in the formation of abundant light and middle distillates.

R. Miandad (2016),according to the author, the liquid oil and gases from pyrolysis have high heating values and maintain the potential to be used as an alternative source of energy. ZSM-5(Nano- zeolite), FCC (Fluid Catalytic cracking), Al_2O_3 (Aluminium Oxide), Red Mud, and NZ (Natural Zeolite) are the most usually used and substantial catalysts. The catalyst remodelling, including doping of the metals such as Ni, Co, Mo, and Zn on acidic catalysts further improves the catalytic activity. A catalyst that has acidity produces more gas yield and low liquid oil yield. In addition, a microporous catalyst shows the same phenomena, while a microporous catalyst increases the liquid oil and char yield with less gas production. The usage of NZ as a catalyst in the pyrolysis process is getting more protruding due to both its ease in availability and financial factor. While pyrolysis by using catalyst encourages lesser temperature, faster chemical decomposition, and superior quality of pyrolyzed products. This method has been studied by some researchers for polyethylene (PE) and polystyrene (PS) using zeolite-Y and ZSM-5 catalysts. The results showed a rise in the gas yield and a decrease in the oil yield. The usage of other catalysts such as silica-alumina and Al-MCM-41 have also been studied by others. Catalytic revolutionizing of waste agricultural polyethylene film over Al-MCM-41 catalyst formed heavier hydrocarbon products than HZSM-5 catalyst. Out of this catalyst, Natural zeolite and Y-zeolite will give better results, it is cost-effective and easily available.

5.1.5. Pyrolysis Reactors:

Pyrolysis is an anaerobic process, done in absence of oxygen which contributes to a higher yield of oil and fastens the decomposition process of plastic. For this purpose, reactors are required. There are several types of rectors used in pyrolysis: fixed-bed reactor, rotary oven/kiln, fluidized bed reactor, and tubular reactor. The following table shows product yield in different types of reactors:

Table No. 1: Reactors and Their Product Yield

Research Paper	Reactor	Product Wt. (%)			
		Liquid Oil	Char	Gases	Temperature
B. Acevedo (2013)	Fixed Bed	59.8	3	4	850°C
B. Acevedo (2013)	Rotary Oven	30	35	31	850°C
B. Fekhar (2020)	Batch	35	30	29	510-520°C
B. Fekhar (2020)	Tubular	32	18	25	510-520°C
Yuan Xue (2015)	Fluidized Bed	57.6	44.4	13.2	675°C

From the above table, it is seen that a fixed bed reactor has a higher oil yield and lesser char and gas production. Temperature is relatively higher than of other reactors. Except for the fixed bed reactor, other gases and char production are considered significant. A fixed bed reactor has excellent flexibility to handle. It can work several tonnes per day.

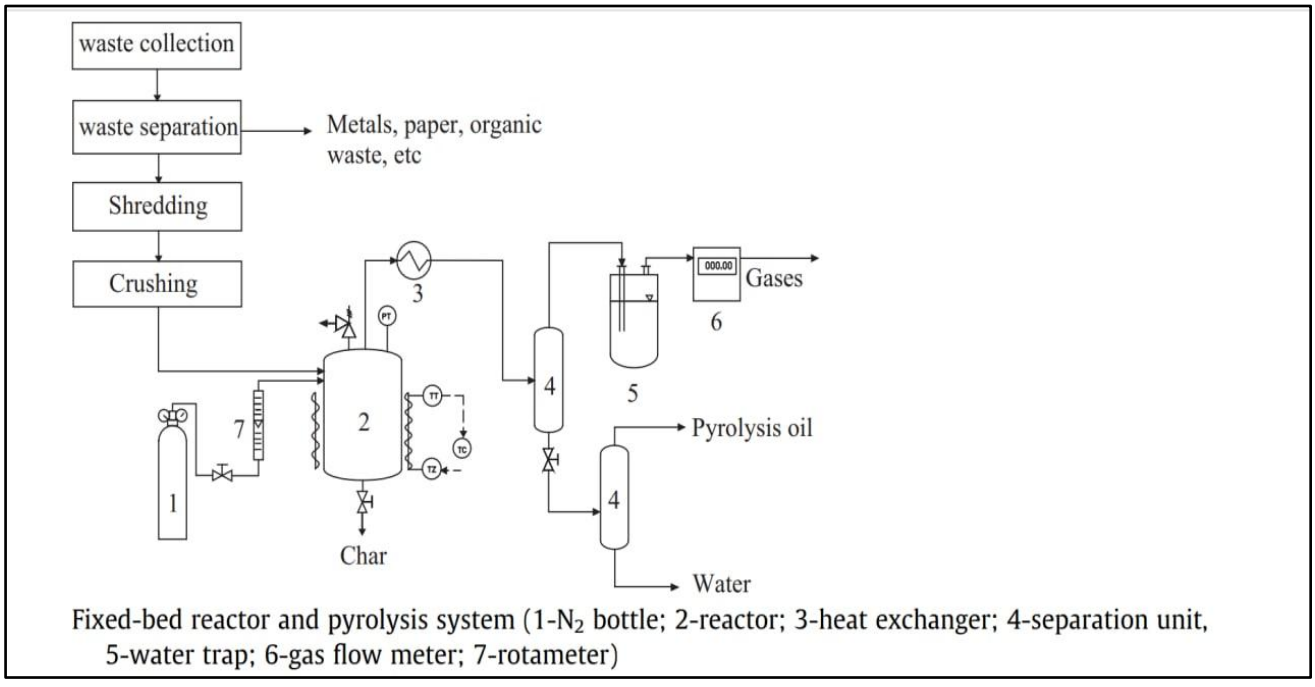

Fig. No. 1. Schematic Diagram Showing Process of Pyrolysis: Dezen (2014)

The collected waste is separated at the plant location. The reduced size of plastic shredding is done. The shredded plastic waste is crushed. Then the crushed plastic waste is fed into the reactor which is coupled with a heat exchanger. Catalyst is stored in an N_2 bottle. Then, in the reactor catalyst and plastic waste is mixed with the help of a rotameter setting at a gradually increasing temperature. Then, in the separation unit produced products are separated and diverted to their particular units. The water trap is placed in the system to cool down the processing system which is fed to the reactor and gases are collected in the gas chamber. Then oil-water is separate.

6. Effect of Pyrolysis on Environment

From pyrolysis, pyrolyzed fuel, char, and gases are obtained. The obtained products need to be examined as they may contain hazardous properties and impact the environment. Hence, the analysis of products obtained is discussed here.

Bhargav Baruah and Pankaj Tiwari (2020), reported that higher temperature increases the oil yield. As per Sim-Dist analysis, showed a rise in the percentage of gasoline and kerosene from 26.2 and 18.3% at 120^{0}C to 45.3 and 47.2% at 236^{0}C, respectively. It is observed that significant reduction in the concentration of aldehydes, ketones, carboxylic acids, and aromatics and an increase in the concentration of alkanes at high pressure. The decrease in the percentage of aromatics occurs due to enhanced cracking and coking reactions at high pressure.

Małgorzata Sieradzka (2020), in that paper gaseous products obtained are studied under Ansys Chemkin-Pro software. Raw material and temperature are influencing factors of pyrolysis oil. Higher temperature increases hydrogen formation and reduction in methane gas formation. As temperature increases, hydrocarbons like C_3H_6 and C_3H_8 decrease while H_2S formation increases which result in corrosion of the pyrolysis plant. Higher HCl content in plastic increases HCl content in RDF.

Dezhen Chen (2014), reported that char is the residue obtained during the pyrolysis process which can be toxic. It may contain inorganic contaminant cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu) and arsenic (As), and organic contaminants like (volatile aromatic hydrocarbons, alkyl phenols, etc.). They are classified as hazardous. Hence, industrial waste is not recommended with MSW during the pyrolysis process. Hence, control devices need to be equipped with a pyrolysis plant. Also, the paper reported that the combined pyrolysis & gasification technology is a better choice for fuel output other than heat from the pyrolysis system. While the single pyrolysis stage is economical the qualities of the products should be required to simplify its application. Pyrolysis alone used in under developing areas and also where there is a rising operation temperature, separation of unsuitable components in the feedstock, and implementation of efficient reactor should be taken to expand the product qualities.

7. Design of pyrolysis Plant for Islampur

From the above-mentioned reviews on plastic, population, waste generation rate in Islampur, and pyrolysis technology; it is seen that the pyrolysis system will be efficient for the city.

- Capacity of plant will be:

Population: According to census,

1991 = 42,459

2001 = 58,330

2011 = 69,743

As the Islampur city id under development and can be expanded in future. Also, from the above census data, it is seen that the population rate is varying and not constant. Hence, the incremental increase method is suitable for population forecasting.

Population in 2021can be = 1,15,127

Plastic waste generation according to CPCB report of 2019:

Total plastic waste generation =115127 X 10.41g = 1,197.32 kg = 1.2 tonne/day

Hence, by considering the future scope of plastic waste generation capacity of the pyrolysis plant can be taken 1.5 tonnes/day.

- The type of pyrolysis adopted will be catalytic pyrolysis due to its production efficiency.
- Rector will be a fixed-bed reactor as it produces lesser gases and char than oil.

8. Conclusion

The pyrolysis technology of extracting RDF getting popularity as an MSW treatment method. The review of the literature showed that the pyrolysis plant has a gasification unit. PS has a greater affinity to produce oil. The stated pyrolysis reactors are fixed-bed, rotary kiln/oven, fluidized bed, and tabular reactors but only rotary kilns and tubular reactors are applied to the wide range of works. The output products from the pyrolysis system are liquid oil, char, and gases. The product yield from the pyrolysis process is greatly influenced by catalysts used, type of reactor, temperature, and heating rate. The gas formation is varying with the system and also increases with an increase in temperature. To produce oil, MPW should be an abundant source. The char from the pyrolysis of MSW is varying, but it could be polluted with heavy metals and organic pollutants, heavy metal concentrations and pyrolysis temperature is necessary. Since gaseous emissions of HCl, and H_2S are related to MPW pyrolysis, control devices always need to be equipped.

Nearby Islampur, the working pyrolysis plant is in Kolhapur city. According to Mr. Sudhir B. Desai (2015), the total plastic waste generated in Kolhapur is 18 tonnes per day and 12000 liters of oil are generated daily from the pyrolysis plant. Production cost is Rs. 14 – 18 per liter and the selling price is Rs. 40 per liter. It is used as diesel for diesel engines and oil-fired furnaces.

Currently, for Islampur city, there is no treatment technology adopted by the municipal corporation. Collected plastic waste is dumped at landfill sites i.e., openly exposed to the environment for the last 4 years. It creates a nuisance, pollution of air, soil, and water, hampering the balance as well as aesthetic of environment, smell and odour are the issues faced by the nearby community. By adopting pyrolysis technology for oil extraction from plastic above issues will be resolved in the future. The well-managed, integrated pyrolysis plant has the potential for the wholesome elimination of plastic waste. It is prominent technology to achieve environmental sustainability implemented worldwide and prove beneficial for Islampur City. It is an anaerobic process. Hence, pollution obstacles can be resolved. The infrastructure of the pyrolysis plant is a closed mechanically operated system. Hence, the smell and odor issue will be resolved. The main objective of plastic disposal and environmental sustainability is achieved. The value-added by-products obtained are beneficial and can be used for other purposes. It will also create opportunities for jobs for local people.

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