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RECYCLING OF PLASTIC WASTE-AN OVERVIEW

Nitul Limbasiya[a], Rashmita Thummar[a] and Amita Upadhyay[b]

[a] Student, ME Environmental Engineering, Sarvajanik College of Engineering & Technology, Surat, Gujarat, India

[b] Asst. Professor,ME EnvironmentalEngineering, Sarvajanik College of Engineering & Technology,Surat, Gujarat, India

ABSTRACT:

Plastics are man-made organic materials that are produced from oil and natural gas as raw materials. The rapid rate of urbanization and development has led to increasing plastic waste generation. The amount of plastic waste in Municipal Solid Waste (MSW) is increasing due to increase in population, development activities and changes in the life style. Mainly two types of plastic such as Recyclable (PET, HDPE, LDPE, PP, PVC, PS) and Non-recyclable (Multilayer & Laminated Plastics, PUF, Bakelite, Polycarbonate, Melamine, Nylon) which are generate the problem of Plastic waste management and badly effects on surrounding environment. It needs to be management and recycling of plastic waste environmentally and economically. Here, overview of the process of converting waste plastic into value added products is explained as a viable solution for recycling of plastics. Recycling of plastic waste using different methods like Mechanical Recycling, Blast furnace feedstock recycling, Coke oven chemical feedstock recycling, Gasification, Liquefaction, Thermal recycling.

Keywords:Plastic waste, Plastic waste management, Recycling of plastic waste.

I. INTRODUCTION

Plastics are man-made organic materials that are produced from oil and natural gas as raw materials. Plastics consist of large molecules (macromolecules), the building blocks of all materials. Plastics can be regarded as long chains of beads in which the so-called monomers such as ethylene, propylene, styrene and vinyl chloride are linked together to form a chain called a polymer. The two main types of plastics include;

- **Recyclable Plastics (Thermoplastics):** PET, HDPE, LDPE, PP, PVC, PS, etc.
- **Non-Recyclable Plastics (Thermoset & others):** Multilayer & Laminated Plastics, PUF, Bakelite, Polycarbonate, Melamine, Nylon etc [8].

As per BIS Codification as notified in Rule 8 (b) of the Plastic Waste (Management and Handling) (Amendment) Rules, 2011, there are seven categories of plastics:

Symbol	Acronym	Full name and uses
1	PET	Polyethylene terephthalate - Fizzy drink bottles and frozen ready meal packages.
2	HDPE	High-density polyethylene - Milk and washing-up liquid bottles
3	PVC	Polyvinyl chloride - Food trays, cling film, bottles for squash, mineral water and shampoo.
4	LDPE	Low density polyethylene - Carrier bags and bin liners.
5	PP	Polypropylene - Margarine tubs, microwave-able meal trays.
6	PS	Polystyrene - Yoghurt pots, foam meat or fish trays, hamburger boxes and egg cartons, vending cups, plastic cutlery, protective packaging for electronic goods and toys.
7	Other	Any other plastics that do not fall into any of the above categories. For example melamine, often used in plastic plates and cups.

Figure 1 Categories of Plastics

Plastic pollution involves the accumulation of plastic products in the environment that adversely affects wildlife, wildlife habitat, or humans.

Plastic Waste Recycling is the process of recovering scrap or waste plastic and reprocessing the material into useful products, sometimes completely different in form from their original state.

A. Sources of plastics waste: - The main sources of plastic waste can be classified as follows:

- Industrial: - Industrial waste and rejected material (so-called primary waste) can be obtained from large plastics processing, manufacturing and packaging industries. Many industries may provide useful supplies of primary waste plastics such as spare-parts for cars, such as fan blades, seat coverings, battery containers, PVC pipes and fittings, tiles and sheets, switch boxes, cable sheaths.
- Commercial: - Workshops, craftsmen, shops, supermarkets and wholesalers may be able to provide reasonable quantities of waste plastics for recovery.
- Municipal Waste: - Waste plastics can be collected from residential areas (domestic or household waste), streets, parks, collection depots and waste dumps [14].

B. Plastics-Indian scenario:-

- Consumption of Plastics: 5000 per annum (t/a)
- Plastics in Packaging: 3000 per annum (t/a)
- Pre-consumer Waste: 100 per annum (t/a)
- Post-consumer Waste: 4900 per annum (t/a)
- Waste available for recycling: 2000 per annum (t/a)

Per Capita Consumption of Plastics:

- India: 4.0 Kg/A
- China: 18 Kg/A
- Other Developed Countries: 20Kg/A.

II. **Literature Review**

GAURAV, MADHUKAR M et al. (2014), studied that the process of converting waste plastic into value added fuels is explained as a viable solution for recycling of plastics. Thus two universal problems such as problems of waste plastic and problems of fuel shortage are being tackled simultaneously. Plastic wastes (low density polyethylene) were used for the pyrolysis to get fuel oil that has the same physical properties as the fuels like petrol, diesel etc. The waste plastics are subjected to depolymerisation, pyrolysis, thermal cracking and distillation to obtain different value added fuels such as petrol, kerosene, and diesel, lube oil etc. Converting waste plastics into fuel hold great promise for both the environmental and economic scenarios. Thus, the process of converting plastics to fuel has now turned the problems into an opportunity to make wealth from waste. They can conclude that the properties of the fuel obtained from plastics are similar to that of petrol and further studies on this field can yield better results [2].

L.B.Bhuyar and A.S. Shahare, studied that the rapid rate of urbanization and development has led to increasing plastic waste generation. The quantum of plastic waste in Municipal Solid Waste (MSW) is increasing due to increase in population, development activities and changes in the life style. Recently, plastic waste has attracted widespread attention in India, particularly in the last five year. Due to littering habits and throwaway culture of rail passengers and inadequate waste management system / infrastructure, plastic waste disposal continue to be a major problem for the railway authorities. It has been observed that due to an inefficient waste collection and transit system in an Indian Railway, a large amount of plastic wastes are not disposed of completely or fails to reach the recycling/reuse chains. They are investigating the role of reverse logistic for effective distribution and recycling of waste of PET bottles at Nagpur Railway station. Also to develop a reverse logistic model by applying quantitative research methodology using survey based approach so that this waste can turn it to be a profitable business model for the Indian railway [3].

Lilies Widojoko, P. Eliza Purnamasari, studied that the possibility of using plastic bottle wastes as an ingredient to the Asphaltic Concrete Wearing Course (AC-WC). They research is explores the effect of adding plastic and cement as ingredient to the mixture of asphalt concrete on the characteristics of Marshall. Plastics that are added are 2:4 and are 6% in weight. It was observed that the optimum bitumen content on the addition of 4% plastic and Marshall Stability increases by 19% compared to the AC-WC without addition of plastic. The positive effect of plastic bottle on the characteristics of Marshall, along with its environmental advantages, makes this material a feasible additive [4].

Miss Apurva J Chavan, has been studied that the apparent disposal which cause environmental pollution. Utilization of waste plastic bags in bituminous mixes has proved that these enhance the properties of mix in addition to solving disposal problems. Plastic waste which is cleaned is cut into a size such that it passes through 2-3mm sieve using shredding machine. The aggregate mix is heated and the plastic is effectively coated over the aggregate. This plastic waste coated aggregate is mixed with hot bitumen and the resulted mix is used for road construction. The use of the innovative technology will not only strengthen the road construction but also increase the road life as well as will help to improve the environment. Plastic roads would be a boon for India's hot and extremely humid climate, where temperatures frequently cross 50°C and torrential rains create havoc, leaving most of the roads with big potholes. She have done a thorough study on the methodology of using plastic waste in bituminous mixes and presented the various tests performed on aggregates and bitumen [7].

M. Punčochář, B. Ruj et al. (2012), studied that the Plasma pyrolysis is an innovative technology for transforming high calorific plastic waste into a valuable synthesis gas (syngas) by means of thermal plasma. The process developed is a drastic non-incineration thermal process, which uses extremely high temperature in an oxygen-starved environment to completely decompose input plastic waste into syngas, composed of very simple molecules: CO, H2 and small amount of higher hydrocarbons. A 20 kg/hr capacity plasma arc pyrolyser for treatment of plastic waste as well as energy recovery options from waste plastic has been indigenously designed, developed, installed and studied its performance at the Central Mechanical Engineering Research Institute (CSIR), Durgapur. After pyrolysis of plastic waste in the plasma arc reactor, generated hot gases (syngas) are quenched through water scrubbing to avoid recombination reactions of gaseous molecules; this inhibits the formation of toxic gases. Syngas composition has been characterized by Gas chromatograph; residue/ash at the bottom of the pyrolyser has been analysed on Neutron Activation Analyser (NAA) [6].

Mochamad Syamsiroa, HarwinSaptoadi et al. (2014), studied that the fuel oil production from municipal plastic wastes by sequential pyrolysis and catalytic reforming processes. Three kinds of municipal plastic wastes were collected from the final disposal site and the small recycling company in Yogyakarta city, Indonesia. Commercial Y-zeolite and natural zeolite catalysts were used in this process. The results show that the feedstock types strongly affect the product yields and the quality of liquid and solid products. HDPE waste produced the highest liquid fraction. The catalyst presences reduced the liquid fraction and increased the gaseous fraction. Furthermore, municipal plastic wastes pyrolysis produced higher heating value solid products than those of biomass and low rank coal [8].

M. Bernardoa, N. Lapa et al. (2012), studied that the present work aims to perform a characterization of chars obtained in the co-pyrolysis of waste mixtures composed by plastics, tires and pine biomass, to provide knowledge about the composition, leaching behaviour and risk assessment of these materials in order to define strategies for their possible valorisation or safe disposal. The chars were submitted to sequential solvent extractions with organic solvents of increasing polarity that allow the recovery of significant amounts of the pyrolysis oils trapped in the crude chars improving the yield of the pyrolysis liquids. An acidic demineralization procedure was successfully applied to the chars and high efficiency removals of the majority of the heavy metals were achieved. The demineralization study also demonstrated that hazardous heavy metals such as chromium, nickel and cadmium are significantly immobilized in the char matrix, and other heavy metals of concern such as zinc and lead will not represent a leaching problem if acidic conditions were not used. The obtained chars present sufficient quality and characteristics to be used as fuel or alternatively, to be used as adsorbents or precursors of activated carbon [5].

Moinuddin Sarker, Mohammad Mamunor Rashid et al. (2012), studied that the waste plastics can become a source of enormous energy with the correct treatment. According to Environmental Protection Agency (EPA) approximately 48 million tons of waste plastic are generated in the USA alone, to be specific PETE-1 (10%), HDPE-2 (19%), PVC-3 (6%), LDPE-4 (23%), PP-5 (14%), PS-6 (9%) and Other-7 (19%). Statistics show that approximately 10% of this plastic is recycled, 25% is incinerated and the remaining 65% is dumped in landfills. Established technology can convert waste plastics into a renewable source of hydrocarbon fuel. This technology plans to acquire waste plastics from City / Local Municipalities and Recycling Facilities. For plastic fuel production purposes the plastics can be collected as commingled or separated into different categories. Another source of large amounts of waste plastic is floating on our oceans and seriously damaging the ecosystem and the environment. These waste plastics can be collected using collection vessels. The waste can then be converted into hydrocarbon fuel either in the collection vessel itself or in off-shore facilities, using established technology [9].

PawarHarshal R. and LawankarShailendra M. studied that the Environmental concern and availability of petroleum fuels have caused interests in the search for alternate fuels for internal combustion engines. Conversion of waste to energy is one of the recent trends in minimizing not only the waste disposal but also could be used as an alternate fuel for internal combustion engines. Waste plastics are indispensable materials in the modern world and application in the industrial field is continually increasing. As an alternative, non-biodegradable, and renewable fuel, waste plastic oil is receiving increasing attention. A review of research papers on various operating parameters have been prepared for better understanding of operating conditions and constrains for waste plastic pyrolysis oil and its blends fuelled compression ignition engine [10].

S.Rajasekaran, Dr. R. Vasudevan et al. (2013), studied that the Waste plastics both by domestic and industrial sectors can be used in the production of asphalt mix. Waste plastics, mainly used for packing are made up of Polyethylene Polypropylene polystyrene. Their softening varies between 110℃– 140℃ and they do not produce any toxic gases during heating but the softened plastics have tendency to form a film like structure over the aggregate, when it is sprayed over the hot aggregate at 160℃. The Plastics Coated Aggregates (PCA) is a better raw material for the construction of flexible pavement. PCA was then mixed with hot bitumen of different types and the mixes were used for road construction. PCA - Bitumen mix showed improved binding property and less wetting property. The sample showed higher Marshall Stability value in the range of 18-20KN and the load bearing capacity of the road is increased by 100%. The roads lay since 2002 using PCA-Bitumen mixes are performing well. A detailed study on the performances of these roads shows that the constructed with PCA –Bitumen mix are performing well. This process is eco-friendly and economical too [11].

S.V.S. Rao, Biplob Paul et al. (2011), studied that the Volume reduction of radioactive solid wastes is carried out with an aim to minimize disposal space requirement. Cellulosic combustible solid wastes like cotton, paper etc. are treated by incineration and the plastic wastes are volume reduced by baling. Compaction of plastic wastes by baling gives low volume reduction factors (3 – 5) and also the resultant waste bale may spring back to original volume after disposal. With a view to achieve higher volume reduction factors, studies were conducted at CWMF on the melt-densification of plastic wastes at 180 - 190℃. The melted plastics were characterized by TGA/DTA & IR Spectroscopy and found that there was no structural loss of the polymer compounds. A melt densification unit (MDU) was set up at CWMF with a facility for melting 20 kg of the plastic waste in each batch in a 200L MS drum. A continuous stack monitor is installed to estimate any release of radioactivity in the off-gases. They are describes the operational experience of melting of different plastic wastes namely polythene sheets & bottles, HDPE pipes and cans, PVC shoe covers and neoprene gloves [12].

III.SIZE REDUCTION TECHNIQUES

A. Cutting:

The first step in the process of plastics waste transformation involves cutting up the waste plastic materials into smaller pieces. This is needed for items such as jerry cans, plastic bottles and buckets which are too large to fit into the hopper of the shredder.

B. Shredding:

The shredding process consists of feeding the cut plastic pieces into a shredder. In the shredder, the rotating blades are driven by an electric motor located behind the machine; the belt transmission is visible on the left. A bag or piece of cloth covers the hopper to prevent pieces of plastic being thrown back by the rotating blades. The shredded material is scooped into bags from the tray to be stored, or is fed directly into an extruder.

C. Agglomeration:

Agglomeration is the coalescing of small particles into a clump. Agglomeration improves the quality of the final product. The plastic waste fed into the agglomerator should be clean, since all foreign objects will be processed together with the plastics, and will be evident in the partially plasticized materials. Also, it will increase the density of the material, which results in a more continuous flow of material in the extruder and thus, in an increase of efficiency. They can only be removed during the extrusion process [8].

IV. FIVE STAGES OF THE PLASTIC RECYCLING PROCESS

Plastic recycling, a term given for processing waste plastic, turning old or scrap plastic into useable products that can re-enter the manufacturing chain.

Stage 1: Sorting the plastic:

Plastic waste needs to be collected by the recycling company; once the plastic arrives at the recycling plant the first stage begins to sort the plastic into the specific types.

Stage 2: Washing Waste Plastic:

Once plastic waste has been identified and separated into one of its many forms the cleaning process can begin, this usually starts with washing to remove paper labels, adhesives and other impurities, all the labels on your plastic containers, bottles.

Stage 3: Shredding the Plastic:

The shredding stage is when plastic waste is taken and loaded onto conveyor belts or directly into huge hoppers that funnel the clean scrap towards rotating metal teeth that rip the plastic into small pellets which are bagged up afterwards ready for testing.

***Stage 4: Identify and classify the Plastic*:**

Once the shredded plastic has been bagged it is then chemically tested and labelled as to its exact specification, this grade of plastic can be used to add to a mix of virgin plastic in the manufacturing run, alternatively the grade plastic can be further recycled.

Stage 5: Extruding:

This is the final stage in the recycling process of plastic. This process involves melting clean shredded plastic and extruding into the form of pellets which then go onto manufacturing the next lot of plastic products [15].

V.METHODS OF PLASTIC WASTE RECYCLING

A. Mechanical Recycling:

Mechanical recycling is the material reprocessing of waste plastics by physical means into plastics products. The sorted plastics are cleaned and processed directly into end products or into flakes or pellets of consistent quality acceptable to manufactures. Pellets are made by melting down the dry plastic flakes and then extruding it into thin strands that are chopped into small, uniform pieces. Mechanical recycling is the preferred recovery route for homogeneous and relatively clean plastics waste streams, provided end markets exist for the resultant recycle [8].

B. Blast furnace feedstock recycling:

Plastics used as a reducing agent at steel mills, iron ore, coke and auxiliary raw materials are fed into a blast furnace and the iron ore melted to produce pig iron. This means that it should be possible to devise a means of using them instead of coke as a reducing agent in the blast furnace process.

Plastics that do contain PVC are fed into the blast furnace after first separating the hydrogen chloride at a high temperature of around 350℃ in the absence of oxygen, as the emission of hydrogen chloride can damage a furnace. The hydrogen chloride thus extracted is recovered as hydrochloric acid and put to other uses, such as acid scrubbing lines for hot rolling at steel mills.

C. Coke oven chemical feedstock recycling:

In this process, plastic waste collected from households is first shredded and impurities such as iron are removed. PVC is removed before the plastics are heated to 100℃ and granulated, then mixed with coal and fed into the carbonization chamber of a coke oven.

The carbonization chamber has combustion chambers on both sides which heat the content indirectly. The waste plastic does not combust inside the chamber due to lack of oxygen, but it is instead cracked thermally at a high temperature to produce coke for use as the reducing agent in coke ovens, hydrocarbon oil which is used as chemical feedstock, and coke oven gas which is used to generate electricity.

D. Gasification:

The gasification process involves heating plastics and adding a supply of oxygen and steam. Sand heated to 600-800℃ is circulated inside a first-stage low-temperature gasification furnace. Plastics introduced into the furnace and if the plastics contain chlorine, they produce hydrogen chloride. The gas from the low-temperature gasification furnace is reacted with steam at a temperature of 1,300-1,500℃ in a second-stage high-temperature gasification furnace to produce a gas composed mainly of carbon monoxide and oxygen. This synthetic gas is used as a raw material in the chemical industry to produce chemicals such as hydrogen, methanol, ammonia and acetic acid.

VI. ENVIRONMENTAL ISSUES ON DISPOSAL OF PLASTIC WASTE

Indiscriminate littering of unskilled recycling/reprocessing and non-biodegradability of plastic waste raises the following environmental issues:

- During polymerization process fugitive emissions are released.
- During product manufacturing various types of gases are released.
- Indiscriminate dumping of plastic waste on land makes the land infertile due to its barrier properties.
- Lead and Cadmium pigments, commonly used in LDPE, HDPE and PP as additives are toxic and are known to leach out.
- Non-recyclable plastic wastes such as multilayer, metalized pouches and other thermoset plastic poses disposal problems.
- Sub-standard plastic carry bags, packaging films (<40μ) etc. pose problem in collection and recycling.
- Littered plastics give anaesthetic look in the city, choke the drain and may cause flood during monsoon.
- Garbage mixed with plastics interferes in waste processing facilities and also cause problems in landfill operations [17].

VII. ADVANTAGES OF REUSE AND RECYCLE OF PLASTICS WASTE

- Conservation of non-renewable fossil fuels – Plastic production uses 8% of the world’s oil production, 4% as feedstock and 4% during manufacture.
- Reduced consumption of energy.
- Reduced amounts of solid waste going to landfill.
- Reduced emissions of carbon-dioxide (CO_2), nitrogen-oxides (NOx) and Sulfur-dioxide (SO_2) [18].

VIII.STRATEGIES FOR REDUCTION OF ENVIRONMENTAL IMPACT OF PLASTICS

A. Reduce the use:

Source reduction Retailers and consumers can select products that use little or no packaging. Select packaging materials that are recycled into new packaging – such as glass and paper.

B. Reuse containers:

Refillable plastic containers can be reused for many times, container reuse can lead to a substantial reduction in the demand for disposable plastic and reduced use of materials and energy, with the consequent reduced environmental impacts.

C. Require producers to take back resins:

Get plastic manufacturers directly involved with plastic disposal and closing the material loop, which can stimulate them to consider the product’s life cycle from cradle to grave. Container and resin makers can help develop the reprocessing infrastructure by taking back plastic from consumers.

D. Legislatively require recycled content:

Requiring that all containers be composed of a percentage of post-consumer material reduces the amount of virgin material consumed.

E. Standardize labelling and inform the public:

Standardized labels for “recycled,” “recyclable,” and “made of plastic type X” must be developed for easy identification [18].

IX. CONCLUSION

From the overview of this study, Plastic wastes are generated from different Sources due to lake of awareness and mismanagement of handling plastic waste. Various strategies are being devised to mitigate the impact of plastic waste in India.There is a great potential for development of different technologies applicable to plastic waste disposal management with energy and material recovery.For recycling to achieve its intended purpose, government authorities must play an important role in the promotion and viability of plastics reprocessing activities not only by their approaches to local waste management but also by the economic policies they adopt.

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