

PAPER • OPEN ACCESS

Plastic solid waste utilization technologies: A Review

To cite this article: Arun Kumar Awasthi *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **263** 022024

View the [article online](#) for updates and enhancements.

Related content

- [Prospects of pyrolysis oil from plastic waste as fuel for diesel engines: A review](#)
V L Mangesh, S Padmanabhan, S Ganesan *et al.*
- [Effects of Waste Plastic on the Physical and Rheological Properties of Bitumen](#)
Mohd Ezree Abdullah, Nurul Asyiqin Ahmad, Ramadhansyah Putra Jaya *et al.*
- [The influence of temperature on the formation of liquid fuel from Polypropylene plastic wastes](#)
M. Martynis, Mulyazmi, E. Praputri *et al.*



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Plastic solid waste utilization technologies: A Review

Arun Kumar Awasthi, Murugesh Shivashankar and Suman Majumder

Department of Chemistry, School of Advanced Sciences, VIT University, Vellore, Tamil Nadu, India

E-mail : mshivashankar@vit.ac.in

Abstract. Plastics are used in more number of applications in worldwide and it becomes essential part of our daily life. In Indian cities and villages people use the plastics in buying vegetable as a carry bag , drinking water bottle ,use of plastic furniture in home, plastics objects uses in kitchen, plastic drums in packing and storage of the different chemicals for industrial use, use plastic utensils in home and many more uses. After usage of plastics it will become part of waste garbage and create pollution due to presence of toxic chemicals and it will be spread diseases and give birth to uncontrolled issues in social society. In current scenario consumption of plastic waste increasing day by day and it is very difficult to manage the plastic waste. There are limited methodologies available for reutilization of plastic waste again. Such examples are recycling, landfill, incineration, gasification and hydrogenation. In this paper we will review the existing methodologies of utilization of plastic waste in current scenario

1. Introduction

Plastic items are used in our everyday life. From greenhouse, coating and wiring, to packaging, films, covers, bags and containers. It is only reasonable to find out a considerable amount of plastic solid waste in the final stream of municipal solid waste. Thermoplastic are used of the total plastic consumption roughly 80% and are used for typical plastics applications such as packaging but also in non-plastic applications such as plastic fibre and coating S.M. Al-Salem et al 2009. With the development of social economy, the demand for electronic products increases rapidly and simultaneously, the fresh speed of these products is becoming progressively faster. Therefore much electronic equipment that is only used for only short time has not been able to satisfy people's needs and becomes obsolete and so the production of waste electrical and electronic equipment shoot up. According to report of UNEP 2009, the global production waste electrical and electronic equipment is around 40 million tons per year. And it can be expected this figure will become bigger in future, Actually, waste electrical and electronic equipment has one of the waste streams of increasing fastest in municipal solid waste Xiaoning Yang et al 2013 . The volume of municipal solid waste generated from residential, commercial and institutional location is increasing due to population growth and the throw away culture that persists throughout mic of the world.



The ability of landfills to handle our waste is limited due to space required and resulting pollution to soil, water, and air. JeongIn Gug, etal 2015 .

Plastic products open up a new epoch in industrial history ever since synthetic polymers were first introduced into industrial scale of production in the 1940s. The utilization of plastic products has considerably and profoundly changed the structure of material research. Some of the advantages of using plastics include high resistance to corrosion, high flexibility to process and low manufacturing cost. With the unprecedented development of industrial society ,the production of plastic waste has been an overwhelmingly growing domain and accordingly, it reasonable to find that the increasing research focus has been drawn to post consumer plastic products including thermoplastic such as polypropylene,polyethylene,polyethylene terephthalate and high density polyethylene. In essence, plastic form a considerable portion 5-15% of the municipal soil waste by weight, which equals to 20-30% volumetric proportion.. These statistics reveal that beneath the convenience due to wide use of plastic products, people should be alarmed about the challenges of pollution and accompanying environmental issues created by plastics waste. Junaid Saleem etal 2015

Given the versatile properties of plastics, such as being light weight, durable and strong, the world population and usage of plastics has increased sharply from 1.5 million tons in 1950 to 299 million tons in 2013. It has been estimated that global plastic production could triple by 2050. However, plastic, as material, are generating environmental problems along their entire life cycles. First ,to produce plastic products, greenhouse gas emissions are generated. Second the characteristics that deem plastic so useful materials also make waste management problematic, and presently, only a small fraction of plastic wastes recycled due to contamination and technical limitation.Third,there is a considerable accumulation of plastic waste in the environment. For example waste patches in the Atlantic and the pacific oceans are estimated to be in the order of 100 mt, approximately 80% of which is plastic. Once in the environment, particularly in the marine eco system, plastic waste can persist for hundred of years. Hence considerable concerns have been focused on plastic waste management Eva Sevigné-Itoiz etal 2015 .

The dumping of waste plastic in open areas is still the most commonly used disposal methods for municipal solid waste in developing countries. Rapid exhaustion of available space for disposing wastes and public opposition against developing new waste disposal site are creating crisis in waste management operation. An approach involving the practice of waste minimization and recycling is needed to extend the service time of existing waste disposal site. Waste mining provides opportunity to provide disposal space for new coming waste and recycle of valuable materials. It evolves the excavation, transfer and processing of buried wastes taken from, an active or closed landfill or dumpsite. This will also help eliminating potential contaminating sources, cost reduction in post closure monitoring. Refuse –derived fuel is a well-known alternative fuel produced from the combustibles in municipal solid wastes which are composed of waste plastic and other material such as textiles ,wood soil etc. Energy recovery as RDF is a preferred option for utilizing plastic wastes when their potential recycling as raw material for product manufacturing is not possible because their physical properties have been damaged during long exposure to sunlight, Biomass usually has fibrous structure and contains oily sticky components which facilitates to form a more dense bulk should be increased to a degree at which transportation expenses become less and used facilitate ease of feeding for incineration. For Refuse-derived fuel utilization, gasification technology has been applied to production of energy from solid wastes. The thermos-chemical process converts solid carbon based materials into combustible gaseous product containing carbon di oxide, carbon mono oxide, hydrogen, methane and other trace gases. These gases can be used for heating, lighting and power generation Chart Chiemchaisri etal 2010 .

The total consumption of plastic will reach 297.5 million tons worldwide by 2015 with Asia the largest plastic consumer accounting for 30% of global consumption over the last years. Plastic waste are estimated at approximately 16% of the total weight of municipal solid waste .polyolefin a common plastic ,is less biodegradable which poses a long term negative effect to the environment after being disposed as solid waste. Studies of the biodegradation of various plastic such as high density polyethylene, low density polyethylene, polypropylene, and polystyrene in neutral soils revealed that same soil microorganism including fungi and bacteria showed a specific metabolic capacity to assimilate these plastics as carbon and energy sources for their growth. For example, some fungi degraded the high density polyethylene of a molecular weight of up to 2800 Sutharat Muenmee etal 2015

Plastic waste can be a cost effective source of chemicals and energy, the recycling of mixed plastic wastes containing poly vinyl chloride not only in the results in the formation of choro –organic compounds in volatile products but also cause serious serious emissions pollution in their applications .it is undesirable to dispose waste plastics by landfill due to high cost and poor biodegradability. Plastic waste can be regarded as a potentially cheap source of chemical and energy. The destruction of waste plastic by incineration is prevalent. But it is expensive and often generates problems with unacceptable emissions. It is also desirable to dispose of waste plastics by landfill due to cost and poor biodegradability. An alternative strategy is that of chemical recycling, known as feedstock recycling or tertiary recycling. Which has attracted much interests recently with the aim of converting waste plastic into basic petrochemicals to be used as chemical feedstock or fuels for a variety of downstream processes. Two main chemical recycling routs are the thermal and catalytic degradation of waste plastic Yeuh-Hui Lin 2009

The rising trend of plastic solid waste can lead to various environmental problems, including pollution. Which serve as a carrier of persistent organic pollutants transferable to aquatic organism. Dealing with these plastic solid waste remains a challenging task in many countries. The widely used traditional landfill is becoming an undesirable way of disposal due to rising cost and poor biodegradability of commonly used petroleum based products. The alternative incineration has been criticized for generating large amounts of bottom ash and various toxic air pollutants, like polycyclic aromatic hydrocarbons, as well as dioxins in case of halogen containing plastics Zhigui He etal 2015

Most of the polymers wastes generates lot of environmentally problems whereas the utilization of wastes is important also from energetic and other aspects. The Thermal degradation of plastic wastes is one of the prospective ways to solve the problem. This way the plastic wastes are converted into fuel for the petrochemical industry. Polyethylene, polypropylene and polystyrene is the targeted polymers. Because their cracking resulted products with favorable properties for further application. According to results the products of polyethylene, polypropylene and even polystyrene cracking have the most favorable properties for further energetic applications. Polyethylene derived fuel has very cetane and octane numbers Andra´s Angyal etal 2007

PVC polymer is widely used polymer in construction sector, electronic equipment and automotive applications. The presence of chlorine in the backbone of PVC is the major concern when it comes to waste management. Because PVC is chlorinated compound, which can arise during waste treatment operations as a consequence of the molecular instability of poly vinyl chloride towards heat and light . Since now a days it is a less usage product in packaging waste, it is not specifically recovered from such waste for recycling, as it is in the case of construction poly vinyl chloride wastes. Due to this reason the presence of PVC in rejected streams are the fraction of packing waste which cannot be mechanically recycled since they are composed of different plastic materials and they are incinerated or landfilled. Pyrolysis process is in more focus now a days for recycling plastic waste, converting them in liquids and gases. Pyrolysis process can be improved by means of dechlorination method which is helpful to produce

the chlorinated compounds when Poly vinyl chloride containing samples are pyrolysis. A. Lopez-Urionabarrenechea et al 2012

Municipal solid waste is a refuse waste material is obtained from residential, commercial, and industrial areas. As the population increases and changing consumption pattern, economic development, fast urbanization and industrialization. The fastest growth of the economy and population have caused municipal waste to proliferate by 28% in the period of decade, from 5.6 million tons in 1997 to 7.65 million tons in 2007. It is predicted to further increase by 30% in 2020 and 39% 2030 compared to the year 2007. Landfill is the easiest technique to handle the waste in bulk quantities. On the other hand, there is lot of barriers and shortage of available space for disposal of the waste. The dependency of landfilling and appropriate waste disposal has been creating the environmental, health and safety problem for the public Sie Ting Tan et al 2015

Plastic industry has witnessed a higher growth in the production of polyethylene, polypropylene, polystyrene, polyethylene terephthalate, poly vinyl alcohol and poly vinyl chloride . Plastic also contribute to our daily life in many aspects. Home use goods nowadays are mainly made of plastic or plastic reinforced materials, from packaging, clothing, appliances and electrical and vehicle equipments, to insulations, industrial applications, greenhouse, automotive parts and aerospace. Most of the plastics items sold become waste either within a year or a single life .Waste polymeric articles present themselves as an advantageous feedstock. Due to light weight of plastic it is converted into saving resources throughout the polymers life cycle. Plastic solid waste recovered through either recycling or energy and fuel recovery. Residual waste from recycling processes should be treated separately, either by thermo chemical means or by incineration. Energy is recovered as heat, which can be used for power generation. Plastic waste recycling processes classified into four categories. Re extrusion (Primary), mechanical (Secondary), chemical (Tertiary) and energy recovery (Quaternary). Each method has unique advantages that make it beneficial for specific applications requirements. Mechanical recycling involves the process of physical treatment while chemical recycling produces chemicals for chemical industry and energy recovery which involves oxidation of the material ,producing heat ,power and gaseous fuels and oils S.M. Al-Salem et al 2010

In India plastic waste used in produce the plastic oil after recycle process. Plastic waste generated from polyethylene, polypropylene, Teflon, Nylon ,plastic bottles, plastic rops. Producing oil from waste will helpful to obtain energy. Blending of waste plastic oil with diesel results better performance as compared to diesel There is increasing diesel consumption, large outflow of foreign exchange and issues for environment have prompted developing countries like India. Developing countries address the issues of energy, oil price hikes and unemployment. In developing countries diesel engine are the most preferred in automobiles due to their excellent performance and better thermal efficiency. But there is disadvantage with diesel engines, they are releasing high amount of nitrogen peroxide and lot of smoke which is effecting human health. There is rapid growth of automobiles vehicles in transportation market, the demand and consumption of diesel oil is increasing. All these factors results in reducing of petroleum fuels resources creating the opportunity of alternative sources of diesel engines. The disposing of waste is a major problem in most of the developing countries. The effective utilization of waste plastic oil in diesel engines. Oil produce from plastic waste for marine application. Plastic waste oil mixed with heavy oil reduces the viscosity of mixed oil mass significantly and improve the performance of engine M. Mani , et al 2011

The management of plastic waste is very difficult and most important issues in today's scenario. Plastic waste is a light weight , reusable material and there is lot of scope to utilize the plastic waste. Plastic waste material is helpful in saving the energy and carbon di oxide gas emissions. Thermal treatment process of

plastic waste is most important process. Plastic waste through incineration, gasification, or decomposition. The benefits of this process are convert the plastic waste in safe way and also reduce the weight and recovery amounts of heat. The incineration process of poly ethylene plastic waste generates high low calorific value. Plastic waste Janusz Wojciech Bujak 2015

Pyrolysis of waste polyethylene and polypropylene plastic was carried in the presence of catalyst. It resulted increase in the production of gases, gasoline and light oil. Disposal and recycle of waste plastic includes landfills, incineration, mechanical recycling and chemical recycling. Landfills creates more environmental issues due to more filling of plastic waste into land. Plastic waste is burning in open atmosphere is become severe issue. Incineration of plastic waste pollute the environment and air due to improper incineration process, the dioxin, furan derivatives and the heavy metals in smoke generate environmental issues. The effective way of plastic waste utilization is chemical recycling, when long carbon chain of the polymers are cracked and resulting gases and liquids hydrocarbon. Chemical recycling is suitable for polyethylene, polypropylene N. Miskolczi ,etal 2009

In todays life plastic become essential part of our everyday life and large part of plastic includes polyethylene,polypropylene and polystyrene .Cracking process of plastic waste produces hydrocarbon products . Steam cracking has limitations of olefin,aromatic and sulphur content . Thermal degradation of polymers ensures high olefin and high aromatic content during liquid cracking András Angyal etal 2010 The plastic waste material has hidden energy content and large quantities of plastic waste are landfilled and incinerated. Space of landfill sites are limited and incineration results in emission of harmful compounds. The degradation of plastic waste is very important process to determine the suitability for waste plastic recycling to fuels N. Miskolczi etal 2012

2. Overview

India is 12th in the list of top 20 countries which disbursing maximum amount of plastic waste .China ranks first followed by countries in Southeast Asia,Sri Lanka,Egypt,Nigeria,Bangladesh and South Africa. As per research study conducted by University of Georgia ,US India accounts for 83% mismanaged waste. The study calculates that the 275 million metric tons of plastic waste generated by 192 countries in 2010, nearly 8.8 million metric tons entered the world's oceans and seas, including the Indian, Atlanta and pacific oceans and Mediterranean and Black seas. The data of costal population and per person waste generation rate is 0.34 kg waste in India. In terms of Kilo of waste generated per person per day and the share of plastic waste therein. In India recycling rates of garbage are unknown and segregation of recyclable and non-recyclable waste is not implemented at house level

(Source: dna news)

Facts about waste

- 275 million metric tons plastic waste generated by 192 countries
- 12.7 million metric tons plastic waste entering the ocean
- 62% the increase in global production of plastic since 1975
- India Rank 12th in the top 20 countries generated mismanaged waste available to enter the oceans

(Source: Science Journal: 'Plastic waste inputs from land into ocean)

3.Utilization of plastic solid waste – Current Technologies

There are large number of technologies have been developed in order to select and sorting out of plastic waste. In the recycling industry , separation of plastic waste items must be finalized within a short time which will help to exact identification of the plastic waste is belongs in contained lot. Plastic waste separation techniques may be manual or automated. In some of plastic waste cases separation techniques exists but are not always applied due to physical state of solid waste Another way of separation of plastic waste is based on density of material . This was is not helpful because most of the waste plastics have close density S.M. Al-Salem etal 2009

Another way to plastic waste separated by triboelectric separation. Which will help to differentiate between two plastic items by rubbing them to each other. In this method triboelectric separator separates different plastic materials on the basis of surface charge transfer phenomenon. When plastic materials are rubbed each other, one material becomes positively and other becomes negatively charged or neutral. Plastic waste can also be separated by using speed accelerator technique. It is developed by Result technology AG based in Switzerland. This technique includes a high speed accelerator to delaminate shredded waste and the separated delaminated material by air classification, sieves and electrostatics. Using XRF techniques different types of flame retardants can also be identified. There is one issue faces by recyclers is the removal of the paint coating on plastics. Grinding can be used to remove coatings, e.g. chrome from plated plastics can be removed by simple grinding. Another way of paint and coating removal is abrasion. Solvent stripping is also used to recyclers, which involves the dipping of the coated plastic into suitable solvents, peeling coatings from the plastic. S.M. Al-Salem etal 2009

3.1 Landfill

Landfill is the traditional approach to manage the plastic waste, but space for landfills is becoming issues in most of the countries in world. Landfill results immediate harm for environment and create long term risks of contamination of soils and underground water by breakdown of plastics which will form pollution There is disadvantage of landfills is sustainability aspect is that no material used to reproduce plastic is recovered again Jefferson Hopewell etal 2009

3.2 Incineration

Incineration discourages the need for landfill of waste plastics and it can be used with recovery of some of the energy part in the plastic. The Energy can vary considerably depending on whether it is used for electricity generation, heat and power .Energy recovery processes is effective way for with highly mixed plastic such as electronic and electrical waste Jefferson Hopewell etal 2009

3.3 Post-consumer use

There is great scope of re-use of post-consumer used plastics in the goods transportation application and for re-use or re manufacturing of plastic items in highly valuable consumer goods.

Re extrusion is the re-introduction of scrap, industrial or single –polymer plastic edges, and parts to extrusion cycle in order to produce products of the similar material. The re extrusion process utilizes scrap plastics which is having similar properties of the original. An example of re extrusion is the injection molding of out of specification low density polyethylene crates. Crates that do not meet the specifications are granule and reintroduced into the recycling loop or the final stages of the manufacturing. Most of the plastic solid waste being recycled is of process, scrap from industry recycled via re extrusion techniques. Households are the main source of such plastic waste. However household plastic waste represents many more challenges and mainly are needs of selective and segregated collection of plastic waste S.M. Al-Salem et al 2010

3.4 Mechanical recycling

It is also known as secondary recycling and is the process of recovering of solid plastic waste which will re-use in mechanical means. It is only applicable to single polymer plastic. E.g. PE, PP, PS etc. Most contaminated plastic waste is more difficult to recycle used by mechanical technique. Separation, washing and preparation of plastic waste are all compulsory to produce high quality, clear, clean homogenous products. There are some issues which are highlighted during mechanical recycling is the degradation and heterogeneity of plastic solid waste because addition polymerization and polycondensation happened due to chemical reaction. These all are reversible in theory, energy or heat supply can cause photo oxidation. Linear and branching of plastic polymer chain can also from the formation of oxidized compounds and extreme climatic condition. There are number of daily used products found in our daily lives which is manufacture from mechanical recycling process such as plastic carry bags, plastic PVC pipes plastic window and door profiles, Mechanical recycling contributing in generates plastic waste in manufacturing, processing and distribution of plastic products is suitable for the use as a raw material for mechanical recycling due to clear separation of different types of plastic resins S.M. Al-Salem et al 2009

Mechanical recycling involves number of treatments and preparation steps being involved during the process. Mechanical recycling process is costly and energy intense process. Mechanical recycling involves following steps.

- Shredding or cutting of plastic waste parts are cut by utilizing the saw and for further processing into flakes
- Separation of paper , dust and other forms of impurities are separated from plastic
- Different types of plastic flakes are separated in floating tank as per density
- Separate single –polymer plastics are milled together
- Washing and drying of plastic waste is required. Chemical washing is also applied for removal of sticky substances on plastics.
- The waste plastic is extruded to strands and then convert into granules to produce a single polymer plastic
- Quenching process which involves water cooling the plastic by water to be granulated

An example of utilizing plastic solid waste is the recycling of poly ethylene terephthalate. There are two approaches have been widely promoted, mechanical and chemical recycling. Once the PET waste has been collected and sorted, it represents a mass for reclamation process lines. Reclamation means washing of the PET bottles and conditioning the plastics to be processed as same as virgin or master batch. Used PET bottles collected from household and some other places compressed and packed by municipalities for transport to recycling plants, PET waste is selected to remove impurities and the waste PET bottles are

than shredded, cleaned, foreign material and remainder material turned into flakes and granules. The recycled materials are then sent sheet preparation where it again melted to produce sheet produced by plastic resin molding techniques are also available for PET and other plastics S.M. Al-Salem et al 2009

3.5 Chemical Recycling

Chemical recycling is a versatile process which convert plastic materials into smaller molecules, usually liquids or gases which are suitable for use of new petrochemical product and plastics. Chemical recycling have proven to useful in production of fuel. The technology behind its success is the de polymerization processes that can result in very sustainable industries which is providing high product and minimum waste. Chemical recycling process are similar to those employed in the petrochemical industry e.g. Pyrolysis, liquid gas hydrogenation, viscosity breaking, steam or catalytic cracking and the use of plastic solid waste as a reducing agent in furnaces. Chemical recycling mainly non-catalytic thermal cracking, catalytic cracking and steam degradation. Chemical recycling has become popular mainly non-catalytic thermal cracking, catalytic cracking and degradation. These are suitable methods for producing different fuels from plastic solid waste. There is lot of interests rising in the development of synthetic products. Chemical recycling is value added development of technology. Different methods for chemical recycling exist in current situation are direct chemical treatment, smelting by furnace, degradation of polyethylene terephthalate and nylon to generate monomer units. S.M. Al-Salem et al 2009 Chemical recycling process both heterogeneous and contaminated polymers. Chemical recycling is very helpful into reuse the plastic solid waste. PET and polyamide are best examples .These polymers can be depolymerized to reproduce monomers and it can be purified by distillation and polymerized again to form the polymer. PET waste dissolved in the dimethyl ester of benzene-1, 4-dicarboxylic acid (di methyl terephthalic acid) and then heated with methanol under pressure at 600 K. This produces the two monomers of PET, ethane-1, 2 –diol and the dimethyl ester. Polyamide (Nylon 6), used in carpets will convert into caprolactum. Polymer, like other high molecular mass organic compounds such as the alkanes in oil, cracked at high temperatures to form small molecule. Mixtures of polymers can be converted into useful compounds by pyrolysis or oxidation.

3.5.1 Chemical Recycling Techniques

Pyrolysis

Pyrolysis is a process when plastic are heated in the absence of oxygen till the waste plastic material decompose into gases and oils. During the pyrolysis, plastic polymers are broke down into small molecules. Pyrolysis at high temperature (>600 deg.c) favour the production of small gas molecules while low temperature (<400 deg.c) produce more viscous liquids. This process is a viable route for the recycling of waste plastics and convert into fuels and gases and also solve the environmental problem because most of the plastic commonly contains toxic and halogen flame retardants.

Plastic is cost effective material and widely used due to easy process, excellent durability, low thermal and electrical conductivity. These plastics can be used in different applications such as insulations, noise reduction, sealing & electronic components .Thermoplastic material such as HIPS, ABS, PVC, polycarbonate and other plastic are most important plastics used in the electronic applications. Plastic components used in electronic applications contain flame retardants to ensure safety. About 30-40% plastic used in electronic applications contain halogenated or non-halogenated flame retardants.

Brominated flame retardants is commonly used in making plastic electronic components. Fluidized reactor is a better equipment for pyrolysis. It has advantage of obtaining more oil products, better temperature control mechanism. Plastic waste is a cheaper source of chemical and energy. Incineration of plastic waste is expensive. Chemical recycling is alternative process which converts waste plastic into petrochemical to be used as a fuel. Chemical recycling ways are thermal and catalytic degradation of plastic waste. Thermal cracking or pyrolysis is a suitable technique and is used in process of the petrochemicals. Plastic material, e.g; polystyrene can be decomposed thermally and high yields to monomers. Polyethylene and polypropylene waste material of the most of municipal plastic waste mixtures. There is lot of studies of effect of catalyst on the catalytic degradation of polymers has been performed by contacting melted polymer with catalyst powders in the reaction vessel and pass the product through fixed bed reactor containing cracking catalyst. Pyrolysis helpful in conversion of post-consumer waste plastic for the production of valuable hydrocarbons and also unique approach for catalytic recycling of plastic waste.

Advantage of Pyrolysis process

- It reduces carbon di oxide emissions
- It reduces landfilling
- It helps to faster commercialization of products
- It helps to product could be used to produce electricity and heat

3.5.2 Gasification

Gasification of waste plastic encourages to decline the landfill space and incineration cost of municipal solid waste plastic. Gasification also helps in producing the fuels or combustible gases from waste. Air in this process is used as a gasification agent and it ensures number of advantageous. The main advantageous in gasification process is using air instead of oxygen alone is become more simple process and also reduce the cost. But there are disadvantageous of the gasification process is presence of the nitrogen in the air. Municipal plastic waste is dumping in open atmosphere is become common practice and it creating environmental problem. Due to dumping of plastic waste in open atmosphere land is shaping into plastic waste mining. Waste mining requires extra space for disposal of new coming plastic waste. Gasification technique is a very good technique for the production of energy from solid waste municipal plastic waste. It is thermal chemical process which converts carbon based material into gaseous product containing carbon di oxide, carbon mono oxide, and hydrogen and methane gas. These gases can be used for heating, lighting, and power generation. There are number of research carried out gasification technique to plastic waste together with biomass. Gasification technique has proven to be a possible way of converting biomass and plastic waste refuse derived fuel into fuel gases. In direct gasification technique, a vertical fixed bed gasification system and air is using as a gasifying agent for biomass utilization. Direct gasification has advantage of simple technique and cost effective operation, but a disadvantage is presence of nitrogen in air could reduce in the calorific value of resulting fuels due to dilution of fuel gases. An ideal attempt of gasification process for plastic solid waste should produce high calorific value gas. The gasification technique for plastic solid waste has been carried out in the field of Poly vinyl chloride, polypropylene and polyethylene terephthalate. There was much attention in the co gasification technique. There is typical example of co gasification technique which is much useful in industrial applications where number of waste such as plastic solid waste, biomass and refuse derived fuel used in the co gasification two step process. After shredding the plastic waste, biomass & refuse derived fuel mixture will be introduced into refuse derived moulder where air sorting take place and steam treatment. Oxygen and steam will be introduced to the first gasifier operates at low temperature (outlet steam temperature of 1300 deg.C).with circulating sand at a temperature of 700 deg.c. In the second stage high temperature

gasifier, the gas from low temperature gasifier is reacted with steam at a temperature of 1500 deg.c to produce a gas composed of carbon monoxide and hydrogen. At the furnace outlet, the gas is cooled to below 200 deg.C to prevent the formation of dioxins and chlorides which contains in plastic solid waste. The gas then passes through a gas scrubber and remaining hydrogen chloride is neutralized by alkalies. This synthetic gas is used as a raw material to produce chemicals such as hydrogen and methanol.

Advantage of gasification process

- It decline the landfill
- It helps to stop the open dumping of plastic waste
- It is cost effective technique

3.5.3 Hydrogenation

The definition of hydrogenation is the addition of hydrogen by chemical reaction. Addition of hydrogen to plastic solid waste have failed. Plastic waste recycling by the addition of hydrogen which is applied in coal liquefaction and convert into naphtha and oil gas. Typical example of hydrogenation of plastic solid waste is depolymerization section, where agglomerated plastic waste is kept between 300 to 400 deg.c to effect depolymerization and dechlorination in the rich chlorine content of poly vinyl chloride. The product is condensed. The condensate, containing some percentage of chlorine content is fed into hydrocracker. The hydrochloric acid is eliminated with the formation of water. The resulting chlorine free condensate and gas are mixed with depolymerize for the treatment in viable cascade controller section. The main outcome of the hydrogenation of plastic solid waste is hydrochloric acid, halogenated solid residue and gas.

Combination of Mechanical and chemical recycling process and other techniques

Applying a combination of mechanical and chemical recycling process prompts the degradation process introducing steam, gas, oxygen, or catalyst. This concept process is the employment of either steam or catalyst in a operation. The main advantage of this process is steam and catalytic cracking of plastic solid waste. This process is known as degradation extrusion, where plastic waste degrades in an extruder utilizing the extrusion operation in recovering some chemicals

There are other recycling techniques of plastic solid waste with other technologies: hydrolysis, glycolysis, fractionation, hydro glycolysis, aminolysis, and methanolysis.

4. Recycling Methodology

Plastic recycling is the process of recovering waste plastic and reprocess again into useful product. Thermoplastics, includes Polyethylene terephthalate, polyethylene and polypropylene have very great potential to be recycled. Thermosetting plastics such as polyester, Epoxy resins cannot be recycled because thermoset polymers are permanently crosslinked during manufacturing, so therefore cannot be re melted and reformed .Recycling is helpful in reducing the plastic waste and also help to reduce the high rate of plastic pollution. Before the recycling, most of the plastic are sorted according to their polymer type

(a) Collection and sorting

Collection and sorting are the first valuable steps for recycling plastic waste, aiming at separating and upgrading raw materials for new plastic manufacturing. Waste plastic should be separate from glass, metals and paper.

(b) Reclamation

Plastic waste material ground to be flaked and cleaned. Based on the type of plastic flake, it can be either transported directly or melted into their individual polymers and reformed pellets

(c) Separation

After reclamation, there is range of separation techniques can be applied. float separation in water can effectively separate plastic material polypropylene, high density polyethylene, linear low density polyethylene, from Poly vinyl chloride, Poly ethylene terephthalate and polystyrene. There are various methods exist for plastic flake sorting: colored flakes from clear PET flakes. New approaches such as laser sorting systems can be used to remove other impurities such as silicones and nylon. Laser sorting uses emission spectroscopy to differentiate polymer types. These systems are likely to improve the ability to separate complex mixtures.

(d) Innovation in Plastic recycling

Innovation in recycling techniques includes increasingly reliable detectors and sophisticated software that collectively increase the accuracy and productivity of automatic sorting. Another advancement in recycling process uses no water and recycle the plastic. In current plastic recycling processes, water used as a coolant. But new method eliminates the need of water by avoiding severe temperature changes. This is achieved by simply skipping the step of the recycling process where plastic is ground and dehydrated by being heated and then cooled with water. The water less method results in recycled plastic pellets that are a slightly better method than others

Plastic waste utilization in other application

Plastic solid waste generated by both domestic and industrial is also suitable for other application such as flexible pavements. Waste plastic includes polyethylene, polypropylene and polystyrene softening between 100 deg. C to 150 deg.c. During softening, there is no harmful or toxic gases produced. But it is easily bonded with concrete gravel and form the film over the concrete pieces providing good water resistance. There is good scope of using municipal plastic solid waste on road to prevent the degradation of roads. Plastic is a versatile material but it become a serious problem after its use. Most of the plastic material are plastic carry bags, plastic cups, films and foams made from polyethylene, polypropylene and polystyrene. The municipal plastic waste is either incinerated or used for landfilling. But these techniques are not an effective way to utilize the plastic waste properly .Utilizing the plastic waste in the asphalt pavement application is a right approach and it will help to dispose the waste by eco-friendly way.

Conclusion

The various techniques of plastic solid waste explained in this paper have contributed the image of plastic solid waste management. Particularly recycling technique is great technique is only to manage the plastic solid waste in current situation. But there are certain disadvantages appear when mechanical recycling is selected as a route of recycling. There are some issues which are highlighted during mechanical recycling is the degradation and heterogeneity of plastic solid waste because addition polymerization and polycondensation happened due to chemical reaction. These all are reversible in theory, energy or heat supply can cause photo oxidation. Linear and branching of plastic polymer chain can also from the formation of oxidized compounds and extreme climatic condition. There is lot of scope to utilize the plastic waste in combination with other materials towards improvement of recycling of plastics

References:

- [1] S.M. Al-Salem P. Lettieri, J. Baeyens, 2009, Recycling and recovery routes of plastic solid waste (PSW): A review ,waste management, **29**(10):2625-43
- [2] Xiaoning Yang, Lushi Sun , Jun Xiang, Song Hu, Sheng Su Xiaoning Yang e 2013, Pyrolysis and dehalogenation of plastics from waste electrical and electronic equipment (WEEE): A review, waste management, **33**(2):462-73
- [3] JeongIn Gug, David Cacciola, Margaret J. Sobkowicz- Review JeongIn Gug, 2015 Processing and properties of a solid energy fuel from municipal solidwaste (MSW) and recycled plastics,waste management,**35**,283-292
- [4] Junaid Saleem , Chao Ning , John Barford , Gordon McKay, 2015 , Combating oil spill problem using plastic waste, waste management , **44**, 34-38
- [5] Eva Sevigné-Itoiz , Carles M. Gasol , Joan Rieradevall , Xavier Gabarrell Eva Sevigné-Itoiz etal 2015, Contribution of plastic waste recovery to greenhouse gas (GHG) savingsin Spain,waste management,**46**,557-567
- [6] Recovery of plastic wastes from dumpsite as refuse-derived fuel and its utilization in small gasification system,2010, Chart Chiemchaisri , Boonya Charnnok , Chettiyappan Visvanathan , Bioresource Technology **101** , 1522–1527
- [7] Sutharat Muenmee, Wilai, Chiemchaisri,Chart Chiemchaisri ,2015, Microbial consortium involving biological methane oxidation in relation to the biodegradation of waste plastics in a solid waste disposal open dump site,,International biodeterioration &Biodegradation, **102**,172-181
- [8] Y.-H. Lin , M.-H. Yang , T.-T. Wei , C.-T. Hsu , K.-J. Wua, S.-L. Lee Yeuh-Hui Lin 2009, Acid-catalyzed conversion of chlorinated plastic waste into valuable hydrocarbons over post-use

commercial FCC catalysts ,

- [9] Zhigui He, Guiying Li , Jiangyao Chen, Yong Huang , Taicheng An , Chaosheng Zhang^c Zhigui He, 2015 Pollution characteristics and health risk assessment of volatile organic compounds emitted from different plastic solid waste recycling workshops, *Environment Intl*, **77**, 85-94
- [10] Andra's Angyal , Norbert Miskolczi, La'szlo' Bartha Andra's Angyal , 2007 , Petrochemical feedstock by thermal cracking of plastic waste
- [11] A. Lopez-Urionabarrenechea*, I. de Marco, B.M. Caballero, M.F. Laresgoiti, A. Adrados A. Lopez-Urionabarrenechea , 2012, Catalytic stepwise pyrolysis of packaging plastic waste
- [12] Sie Ting Tan , Wai Shin Ho , Haslenda Hashim , Chew Tin Lee , Mohd Rozainee Taib , Chin Siong Ho Sie Ting Tan , 2015, Energy, economic and environmental (3E) analysis of waste-to-energy(WTE) strategies for municipal solid waste (MSW) management in Malaysia
- [13] S.M. Al-Salem, P. Lettieri, J. Baeyens Review S.M. Al-Salem, 2010, The valorization of plastic solid waste (PSW) by primary to quaternary routes: From re-use to energy and chemicals
- [14] M. Mani , G. Nagarajan , S. Sampath M. Mani , 2011, Characterization and effect of using waste plastic oil and diesel fuel blends in compression ignition engine
- [15] Janusz Wojciech Bujak 2015 , Thermal utilization (treatment) of plastic waste
- [16] N. Miskolczi , A. Angyal , L. Bartha , I. Valkai N. Miskolczi , 2009, Fuels by pyrolysis of waste plastics from agricultural and packaging sectors in a pilot scale reactor
- [17] N. Miskolczi , R. Nagy N. Miskolczi et al 2012, Hydrocarbons obtained by waste plastic pyrolysis: Comparative analysis of decomposition described by different kinetic models
- [18] Jefferson Hopewell , Robert Dvorak, Edward, 2009, Plastic recycling: Challenge and opportunities