*International Research Journal of Environment Sciences*_____ ISSN 2319–1414
Vol. **2(12),** 84-88, December **(2013)** *Int. Res. J. Environment Sci.*

Review Paper

A Review of Plastic Waste Management Strategies

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Available online at: www.isca.in, www.isca.me
Received 2nd December 2013, revised 10th December 2013, accepted 20th December 2013

Abstract

Plastics have been used widely in both water and food packaging due to their natural properties such as inertness and low bulk densities, which make them suitable mover materials and little risk to contaminants. Plastic bottles and sachets have become prevalent all over the country, particularly, urban areas. The packaging revolt has not been backed by proper plastic waste management policy, which has left a lot of cities in India littered with plastic wastes, hence, creating horrible visual troubles and other community health problems. Growing environmental awareness and reduction in available landfill capacity have prompted plastic recycling programmes in most developed countries. Currently, however only between 5 to 25% of plastic waste is being recycled. The paper discusses prospects of plastic waste management schemes. It is concluded that the existing rate of environmental worsening is likely to continue unless long term remedial measures are adopted for plastic wastes management in the country.

Keywords: Plastics, packaging, recycling, plastic waste management.

Introduction

Plastics have made significant contribution in almost every field of human activity today – agriculture, medical, transportation, piping, electrical and heat insulation, packaging, manufacturing of household and electronic goods, furniture and other items of daily or specific use. Plastics in medical products like disposable syringes, blister packing of tablets and capsules, joint replacement prostheses, inter venous (IV) fluid bottles, blood bags, catheters, heart valves, etc., have significantly helped supporting the human life. Medical devices made of plastics are implanted into the human body.

Packaging is one of the most important applications of plastics. In fact, about 40% of plastic materials worldwide are used in packaging applications. Plastics have contributed in creating a sustainable, hygienic, energy efficient, cost effective and environmental friendly packaging system. Versatility of plastics has allowed creating an efficient pilfer proof, hygienic and cost effective packaging of food products like milk, spices, edible oil, bread, confectioneries, rice, wheat flour, snack foods and various types of medicines. Plastics are used for packaging of toiletries, cosmetics and host of other consumer products of daily and special purpose use required all – rich or poor in urban cities or in the villages.

This has been possible due to the following attributes of plastic materials: i. Safe and hygienic – inert and chemical resistance, ii. Light weight and non-breakability, iii. Excellent barrier properties - enhancing shelf-life, iv. Superior impact resistance, v. Sterilizable and resistance to bacterial and other microbial growth, vi. Transparency as well as opacity, vii. Lower fuel consumption and product loss during transportation.

Contribution of plastics to human health is difficult to ignore. Plastic based packaging with the above-mentioned properties ensures reaching the best, hygienic and unadulterated product to the masses.

Despite all these benefits, plastics packaging in general, and plastic bags / carry bags – which are a part of the packaging system, are under the scanner. Plastics are blamed for series of health, safety and environmental problems. Non-biodegradability of plastics is attributed towards causing waste management problems and choking of the drains in urban cities.

The solution to waste management problem lies in segregation of dry and wet solid waste at the source for which an effective mass awareness campaign is very important. Creation of efficient solid waste management infrastructure coupled with encouraging establishment of recycling centres would help address the MSW problem. Plastics can be recycled to produce articles for mass use augmenting the concept of resource management. Many useful products have been developed with recycled plastics and large number of people is employed in these activities in small, micro and informal sectors. An informal industry estimate put the recycling figure of India at around 1.5 Million Tons – close to 50% of plastics used for packaging applications. This is a very high recycling ratio. Recycling ensures that the unwanted and discarded plastics waste does not remain in road side nor it is carried to the landfill.

Apart from the conventional recycling, which is popular in India, alternate processes of plastic recycling are also required to be encouraged. Low-end, mixed and comingled plastics waste

can be used safely for co-processing in cement kilns. Industrial fuel can be produced from all types of mixed plastics waste. Plastic waste has been used to construct asphalt roads. All these processes have been successfully tried and established in Indian conditions. Adherence for abiding to safe norms while recycling, as stipulated by the regulatory authorities, is a must. Proper education, facility, incentives and awareness can achieve this goal.

However, some types of plastic waste like multi layer laminates, EPS, etc. are not easily recyclable by conventional process. Sometimes when different types of plastic waste, which are otherwise easily recyclable individually, get mixed with different groups of plastics in the waste stream forming, what we call, comingled plastic waste, recycling becomes difficult. Such type of plastic waste, generally, is abandoned by the waste pickers creating waste management problem.

In India, the infrastructure for handling of solid waste particularly in urban areas is woefully inadequate. Poor littering habit of the general public has aggravated the problem. Union as well as different state government authorities had indeed imposed restrictions on use of thin plastic carry bags to contain the waste problem indirectly. However, it is recognized that various Government Notifications were not implemented effectively. This led to an increased pressure on the local authorities to take more stringent measures including complete ban on plastic bags. It is realized that complete ban on plastic carry bags is not the solution – rather it would encourage use of alternate materials creating an increased environmental pollution in the real sense and ultimately leading to the cause of climate change – a more dreaded reality the world is facing today. A voluntary cooperation and self-regulation by the industry and the public at large and adequate action by the Government Authorities can solve the waste management problem.

Life Cycle Impact Analysis (LCIA) is an important and modern scientific tool to analyse the total environmental impact of a product or activity on the earth. The sum total of the environmental impact of a product or activity from its inception, production, transportation to market place, usage and reusage, recycling and disposal for disintegration or recovery of energy or the basic constituents of the material for producing the same or other materials of use – gives the indication of the product or activity's environmental friendliness or otherwise, compared to an alternative. Outcome of many LCA studies conducted by credible academic institutions and independent professional organisations of repute have proved that plastics have much less adverse impacts on the environment pollution as compared to their alternative.

Types of Plastics and their Major Applications

The various types of plastics and their major applications are as follows:

Thermoplastics: These types of plastics become soft when heated, they can be moulded or shaped with pressure when in plastic state and, when cooled, they solidify and retain the shape or mould. Some common thermoplastics with their uses and properties are as follows: -

Polyethylene terephthalate (PET): Some common properties are: i. Tough and clear, good strength and stiffness, chemical and heat resistant, good barrier properties for oxygen and carbon dioxide. ii. It is used in-packaging, soft drink and mineral water bottles, fibres for clothing, films, food containers, transport, building and appliance industry (as it is fire resistant), etc.

High density polyethylene (HDPE): Some common properties: i. Good process ability, excellent balance of rigidity and impact strength, excellent chemical resistance, crystalline, melting point (130-135^{0}C), and excellent water vapour barrier properties. ii. Used for making blow moulded products (various types of containers, water bottles), pipes, injection moulded products (storage bins, caps, buckets, mugs), films (carrier bags), etc.

Polyvinyl chloride (PVC): Its properties are: i. Versatility, energy saving, adaptability to changing time and environment, durability, fire resistance. ii. It is used in industries such as building and construction, packaging, medical, agriculture, transport. Also used for making wires and cables, furniture, footwear, domestic appliances, films and sheets, bottles, etc.

Low density polyethylene (LDPE): Characteristics of LDPE are: i. Easy process ability, low density, semi crystalline nature, low melting range, low softening point, good chemical resistance, excellent dielectric properties, low moisture barrier, poor abrasion and stretch resistance. ii. It is used for making carrier bags, heavy duty bags, nursery bags, small squeeze bottles. Also used in milk packaging, wire and cable insulation, etc.

Polypropylene (PP): Properties are: i. Low density, excellent chemical resistance, environmental stress resistance, high melting point, good process ability, dielectric properties, low cost, creep resistance. ii. Used for making bottles, medical containers, pipes, sheets, straws, films, furniture, house wares, luggage, toys, hair dryer, fan, etc.

Polystyrene (PS): Some of the properties of polystyrene are: i. Glassy surface, clear to opaque, rigid, hard, high clarity, affected by fats and solvents. ii. Used for making electrical and communication equipments e.g. plugs, sockets, switch plates, coil forms, circuit boards, spacers and housings. Also used for making containers, toys, wall tiles, baskets, cutlery, dishes, cups, tumblers, dairy containers, etc.

Others plastics: There are many other types of plastics except these six types, often used in the engineering sector. Examples include polycarbonate (PC), nylon, and acrylonitrile butadiene styrene (ABS).

Thermosets: Thermosetting materials are those which once set cannot be remoulded/softened by applying heat. It includes phenol, melamine and urea formaldehyde, unsaturated polyester, epoxy and polyurethanes. These materials are not recyclable.

The management of plastic waste is to be planned in such a manner that the plastic waste generated from various sources is suitably taken care of. The various sources of plastic waste are shown in figure 1.

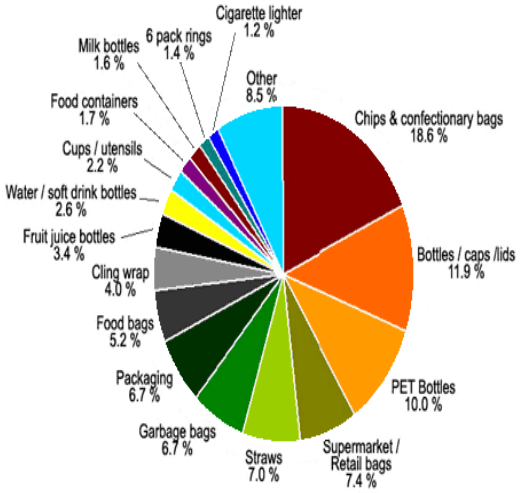

Figure-1
Sources of Plastic Waste

An overview of plastic waste management is exhibited in figure 2. The conventional and new technologies adopted for plastic waste management are summarized here.

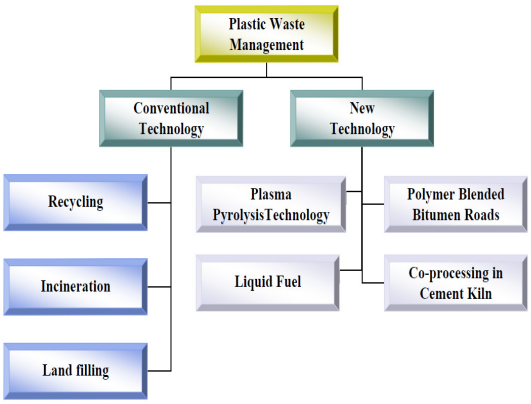

Figure-2
An Overview of Plastic Waste Management

Conventional Technology for Plastic Waste Management

The conventional technology for plastic waste management involves recycling, landfilling and incineration**.**

Recycling of plastics through environmentally sound methods: Recycling of plastics must be carried out in such a manner that it minimizes the pollution level throughout the process and, as a result, increase the efficiency of the process and conserve the energy. Plastic recycling technologies have been divided into four general types-primary, secondary, tertiary and quaternary.

Primary recycling includes processing of scrap/waste into a product with features similar to the original product.

Secondary recycling involves processing of waste plastics into products that have characteristics dissimilar from those of original plastic products.

In **Tertiary** recycling, basic chemicals and fuels are produced from plastic scrap as part of the municipal waste stream or as a segregated waste.

Quaternary recycling reclaims the energy content of the scrap plastics by burning/incineration. This process is not in use in India.

Steps Involved in the Recycling Process are: Selection The recyclers need to select the wastes which are suitable for recycling.

Segregation The plastic waste need to be segregated as per the codes stated in the BiS guidelines (IS:14534:1998).

Processing After selection and segregation, the pre-consumer waste shall be recycled directly. The post consumer waste (used plastic waste) shall be washed, shredded, agglomerated, extruded and granulated.

Landfilling: This is a traditional approach to waste management, but space for constructing landfills is becoming limited in some countries. A well-managed landfill site results in restricted instant environmental harm further than the impacts of collection and transportation, though there are long-term threats of contamination of groundwater and soil by few additives and breakdown by plastics products, which can turn out to be constant organic pollutants[1]. A main drawback of landfills from a sustainability feature is that no one of the material resources used for the production of plastic is recovered—the material flow is linear rather than cyclic. In U. K., a landfill tax is functional, which is currently set to rise every year so as to increase the incentive to turn away wastes from landfill to recovery actions[2].

Incineration: This process lessens the need for landfilling of plastics wastes, but, there are worries that hazardous materials may be released into the atmosphere during this process. For example, halogenated additives and PVC are usually present in mixed plastic waste which leads to the threat of dioxins, furans and other polychlorinated biphenyls being released into the

environment[3]. The choice of incinerators is very important. Though it is not likely to be done in a controlled manner so as to reduce the pollution due to off-gas i.e. dioxins and furans to wanted standards. So this method of plastic waste management is usually not preferred. The treatment cost of the gases is frequently more than the energy recovered.

Modern incineration technology has answers to tackle any incineration problem without polluting the environment and, in many cases, recovering the calorific value out of the waste being incinerated. Heavily contaminated plastic waste collected from different waste streams can be utilized for energy recovery by waste incineration plants. Cost of this system of recovery is considered highest among all the other alternatives. When considering incineration as an option, it is to be remembered that plastic waste incineration may lead to generation of harmful pollutants like dioxins and furans, which is highly undesirable.

Recent Technologies for Plastic Waste Management

The recent technologies for plastic waste management are listed here.

Polymer Blended Bitumen Road: The process of road laying using waste plastics is designed and the technique is being implemented successfully for the construction of flexible roads at various places in India. A brief description is given in the schematic diagram shown in figure 3.

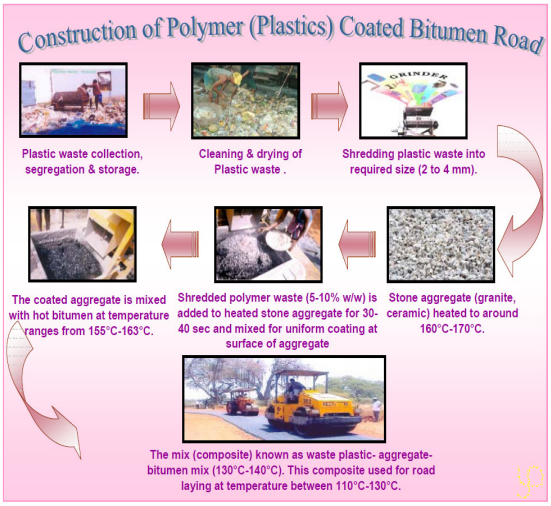

Figure-3
Schematic flow diagram of plastic coated bitumen road construction

Co-processing of Plastic waste in Cement Kiln: Plastic waste generated from different cities and towns is a part of municipal solid waste (MSW). It is a matter of concern that disposal of plastic waste is causing many problems such as leaching impact on land and ground water, choking of drains, making land infertile, indiscriminate burning causing environmental hazards etc. Plastic waste, being non-biodegradable, is littered in most of the cities/towns and their-by giving an ugly appearance. It is estimated that approximately 15,342 tonnes/day (TPD) of plastic waste (on per capita basis) is generated in the country. To get rid of plastic waste disposal problems, Central Pollution Control Board (CPCB) in association with M. P. Pollution Control Board has taken initiative to use the plastic waste in cement plant at ACC Kymore (Katni, M. P.). The stack monitoring results, revealed that emission values are found below the standard set for Common Hazardous Waste Incinerators. After getting encouraging results, CPCB has granted permission to many cement plants to co-process the hazardous and non-hazardous (including plastic) waste in their kilns after trial burns.

Co-processing of plastic waste as an Alternative Fuel and Raw Material (AFR): Co-processing refers to the utilization of waste materials in industry process such as cement, production of lime or steel and power stations or any other large combustion plants. Co-processing shows replacement of primary fuel and raw material by waste recovering industry and material from waste. Waste materials, for instance, plastic waste used for co-processing are referred to as alternative fuels and raw material (AFR). Co-processing of plastic waste suggests advantages for cement industry as well as for the Municipal Authorities responsible for waste management. In other hand, cement producers can save fossil fuel and raw material consumption, contributing the more eco-efficient production. In addition, one of the advantages of recovery method used in existing facility would be, eradicating the need to invest on other plastic waste practices and to secure land filling.

Co-processing of Plastic waste in Cement Kiln: One of the most effective methods of recycling of plastics waste for recovery of energy is its use as an alternative fuel in cement kilns. Apart from recycling of plastic for making new products and saving energy, there are also projects which aim to turn plastic into new energy sources. Plastic is prepared from crude oil, which is the same raw material from which fuel is made. Thus, some scientists have made it their goal to turn waste plastic back to crude oil so that it can be reused for powering engines. With the help of this method, waste plastic is not only put to actual use, but it also helps to save the scarce crude oil resources left on earth. The high temperature used in the cement kilns gives a scope for use of even some type of plastic waste contaminated with toxic chemicals like pesticides and some other hazardous materials without creating any increased emissions in the air or water. No segregation or cleaning is required for such type of disposal. Low-end plastic waste, which creates a waste management problem, may provide the vital energy to the cement industry. At 10% replacement rate, 170 Cement Kilns in India could dispose of the entire plastic waste generated in the country today with additional benefit of reduction in the use of fossil fuel- coal.

Plasma Pyrolysis Technology (PPT): Plasma Pyrolysis is a technology, which put together the thermo-chemical properties of plasma with the pyrolysis process. The extreme and versatile heat generation ability of plasma pyrolysis technology enables it to dispose of all types of plastic waste.

Process Technology: In Plasma Pyrolysis, initially the plastic waste is fed into the primary chamber at 850^0C through a feeder. The waste material dissociates into carbon monoxide, hydrogen, methane, higher hydrocarbons etc. Induced draft fan drains the pyrolysis gases and plastic waste into the secondary chamber. In this chamber, the pyrolysis gases are combusted in the presence of excess air. The inflammable gases catch fire because of high voltage spark. The temperature in the secondary chamber is maintained at 1050^0C. The hydrocarbon, hydrogen and CO are combusted into water and safe carbon dioxide. Conditions are maintained such that it eradicates the possibility of formation of toxic gases. The conversion of organic waste into non toxic gases (CO_2, H_2O) is more than 99%. The excessive conditions of plasma kill stable bacteria such as bacillus stereo-thermophilus and bacillus subtilis right away. Segregation of the waste is not necessary, since very high temperatures make sure the treatment of all types of waste without discrimination.

Conversion of Plastics Waste into Liquid Fuel: This technology is not very complicated. As feedstock, it can accept a broad range of plastics, including those that are unwashed, unsorted, or which are hard to recycle. Once the material is obtained, it can be cut up into small pieces prior to its utilization, but current advancements have led to the capability of putting larger pieces of plastic directly into the system. To start the process, waste is laden into a hopper with a forklift. The materials which can be loaded include plastic car bumpers, fuel tanks, product packaging, component holders, agricultural film, and pharmaceutical packaging. Natural gas is burnt to generate heat and get the process started once the hopper is in the reactor. At this point a catalyst helps in breaking the plastic hydrocarbons into shorter chain of molecules. The off-gases that are not going to be collected as fuel are used to produce heat and keep the process going. The fuel oil and diesel are condensed from a gaseous state into a liquid state, which are collected as the process continues. They are placed into temporary fuel tanks. The process is controlled by an automated system.

Conclusion

Plastic Waste Management has assumed great significance in present day context. Various schemes are being implemented to mitigate the impacts of plastic waste in India. Recycling is one such scheme for waste management of plastic products. It makes rising sense environmentally as well as economically and current trends demonstrate a considerable increase in the rate of recovery and recycling of plastic wastes. These trends are expected to continue, but some significant challenges still exist from both technological factors and from economic or social behaviour issues relating to the collection of recyclable wastes, and substitution for virgin material. Joined with efforts to increase the specification and use of recycled grades as replacement of virgin plastic, recycling of waste plastics is an efficient way to improve the environmental performance of the polymer industry.

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