Plastic Waste Management

(An Overview)

State Pollution Control Board-Sikkim,
Govt. of Sikkim,
Deorali, Gangtok.

REUSE
REDUCE
RECYCLE

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1. Introduction

In developing countries like India, management of solid wastes is a major challenge and the rapid pace of development in many ways has worsened the situation. The waste piles are increasing rapidly and concerned authorities/ agencies are unable to upgrade or scale up the facilities required for proper management of such wastes. Lack of organized system of collection of waste, to a great extent, has led to the poor state of municipal solid waste (MSW) management and increasing littering habits.

CPCB has estimated that 1,27,486 TPD (Tons per day) municipal solid waste is generated in the Country during 2011-12 based on the information received from State Pollution Control Boards/ Pollution Control Committees (in between the year 2009-12). Out of which, 89,334 TPD (70%) of MSW is collected and only 15,881 TPD (12.45%) is processed or treated. Hence, huge amounts of waste are dumped wrecking havoc on the state of environment. It is high time that proper management of MSW is undertaken by the stakeholders before the situation gets out of hand.

Likewise, Sikkim being a part of India is also severely struggling with the difficulty in management of MSW. Our State is an emerging tourism destination and front-runner in environmental issues; therefore, there is an urgent need to establish an organised system to contain the ever rising problem of solid waste management before it gets out of hand.

2. Solid Wastes profile of Gangtok.

MSW collection by G.M.C in the State Capital has recorded steady rise in Solid waste generation as evident from the information received from G.M.C hereunder:

Year	Quantity (TPD)
2011-12	25
2012-13	35
2013-14	40

Annually 14,600 MT of wastes are being collected which ends up in dumping site at Martam, East Sikkim. The densities of municipal solid waste are between 350 and 550 kg/m^3 in Indian cities (CPHEEO manual). Accordingly, assuming density of waste at Gangtok to be 450kg/ m^3, volume of wastes collected annually stands at 32,444m^3 which is equivalent to filling up Palzor Stadium 16ft high annually. Figure 1 shows the composition of waste being collected from Gangtok town and it is evident that the waste consists of around 66% organic fraction and remaining is inorganic fraction which amounts to 4,946MT per annum. Accordingly, Total solid waste generation in the State including floating population is approximately 165 Metric Tonnes Per Day (TPD) or 60178 Metric Tonne Per Annum (MTPA) out of which 39717 TPA is bio-degradable fraction, 20,461 TPA non bio-degradable fraction. The volume of waste is eequivalent to filling of Palzor Stadium 65ft high.

The huge percentage of organic fraction can be completely treated in the compost yard. Hence, if this remaining inorganic fraction is prevented from reaching the dumping site by way of material recovery and recycling, ideally, almost entire waste reduction can be achieved.

At present, plastic waste is being collected for recycling in an unorganised way by few scrap collectors. During collection & transportation of waste by GMC trucks, labourers try to salvage few recyclables from the garbage and while transporting it to disposal site at Martam, they sell it, at the rate of Rupees ten per kg, to scrap collector Mr. M.D.Aalam who has a makeshift collection facility in a private holding of Mr. Bikram Rai, on NH 31A, Namli, East Sikkim. It is reported that around one truck load of recyclable plastic waste is sent to Siliguri every month. In addition, scraps generated from industries are collected by local youths and it gets sold off to Mr. M. D. Aalam.

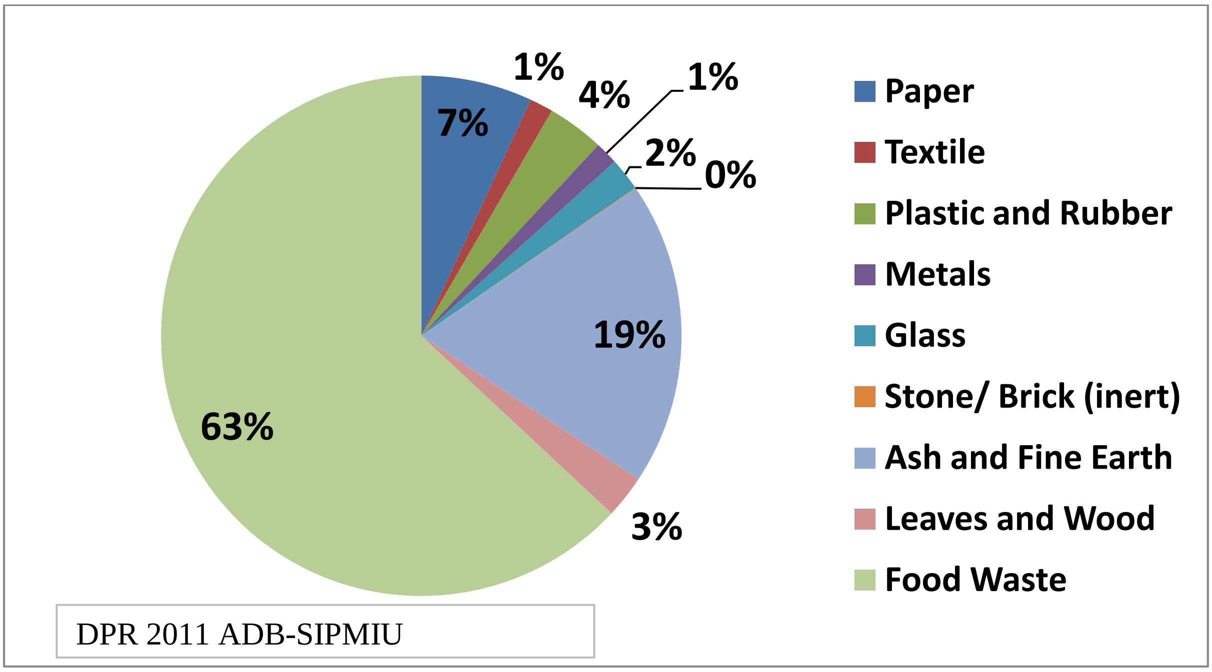

Figure 1. Waste composition at Gangtok.

3. Legal Framework for solid waste management

Environmental Laws	**Salient features**
The Batteries (Management and Handling) Rules, 2001	i. It cover Lead acid battery ii. Responsibilities of Manufacturer, Importer are prescribed wherein they are required to buy back used batteries and ensure setting up of collection centres; and create public awareness iii. Responsibility of Dealers, consumer & consumers are prescribed wherein dealers are required to get registered with the SPCB and also giving appropriate discount on each returned battery; consumer & bulk consumer requires to hand over used battery to dealers, manufacturer, registered recycler etc.
The Plastic Waste (Management and Handling) Rules 2011	i. SPCB as prescribed authority for registration, manufacturer and recycling ii. enforcement of the provisions of these rules relating to the use, collection, segregation, transportation and disposal of the plastic waste rests with Municipal Authority. iii. Municipal Authority has to seek the assistance of manufacturers of plastic carry bags, multilayered plastic pouches or sachets or of brand owners using such products for setting up collection system for such wastes. iv. the municipal authority may work out the modalities of a mechanism based on Extended Producer's Responsibility (EPR) involving such manufacturers, registered within its jurisdiction and brand owners with registered offices within its jurisdiction either individually or collectively, as feasible or setup such collection systems through its own agencies; v. provides for the municipal authority to encourage the use of plastic waste by adopting suitable technology such as in road construction, co-incineration etc.
The E-waste (Management and Handling) Rules 2012	i. Applicable to producer, consumer or bulk consumer, collection centre, dismantler and recycler. (electrical and electronic equipment or components specified in Schedule I) ii. Not applicable to batteries as covered under the Batteries (M &

	H) Rules 2001; Micro and small enterprises; radio-active wastes as covered under the provisions of the Atomic Energy Act 1962. iii. responsibility of Producers for ensuring: a) Collection of e-waste generated during the manufacturing of EEE and channelizing it for recycling or disposal. b) Collection of e-waste generated from the 'end of life' of their products in line with the principle of 'EPR' and to ensure that such e-wastes are channelized to registered dismantler or recycler. Producer shall, as necessary, ensure collection and channelization by authorizing collection agencies. c) Setting up collection centres or take back systems either individually or collectively d) Financing and organizing a system to meet the costs involved in the environmentally sound management of e-waste generated from the 'end of life' of its own products and historical waste. e) Creating awareness iv. Responsibility of Collection centres are prescribed as: a) Obtaining Authorization b) Ensuring safe storage and prevention of environmental damage v. Responsibility of consumer/ bulk consumer: a) Disposal of discarded e-waste with authorised collection centres, registered dismantlers b) Maintenance of records by bulk consumers.
The Bio-medical Waste (Management & Handling) Rules 1998	i. Only segregated non bio-medical solid waste generated in Health Care Facilities and treated bio-medical wastes shall be collected and transported for disposal by Municipal body.
The Municipal Solid Wastes (Management	i. Municipal authority responsible for implementation of the Rules, and for infrastructural development for collection,

& Handling) Rules, 2000	storage, segregation, transportation, processing and disposal of municipal solid wastes. ii. Secretary, Department of Urban Development has overall responsibility of the enforcement of the MSW(M&H), Rules 2000 in the metropolitan cities. iii. The District Magistrate of the concerned district has to enforce these rules within the territorial limits of their jurisdiction. iv. SPCB has to monitor the compliance of the Standards regarding ground water, ambient air, leachate quality and the compost quality including incineration standards as specified under Schedules of the said rules. v. SPCB issues authorization to the municipal authority or an operator of a waste processing and disposal facility. vi. Guidelines on Management of MSW, specification for landfill sites, standards for composting, treated leachates & incineration are laid down in Schedules of the said rules.

4. Deficiencies of Current Waste Management practices [Operation of Municipal Solid Waste Management & Treatment Facility (MSWTF)]:

1. Non segregation of waste at Source
2. Absence of Waste reduction at source
3. Absence of community waste receptacle for recyclable items cardboard, plastics, news paper, metals, glass etc.
4. Lack of organised waste recycling channel.
5. Absence of community waste receptacle for items like used cell & battery (other than lead battery), bulbs (CFL and tube lights), electrical and electronic wastes.
6. Non segregation during collection and transportation of waste
7. Commingled waste used for composting
8. Improper segregation/ sorting approach at the Martam, MSWTF; instead of chain of segregation methods only density & size separation are adopted. Ideally segregation at MSWTF should have manual material recovery at the first stage followed by density separation, shredding and (depending of waste composition electrical & magnetic separation) finally size separation.
9. Unskilled and untrained manpower for composting process.

5. Steps required for reviving the MSWMTF

1. Massive awareness programme
2. Implementation of MSW programme under Mission Mode.
3. A specific day can be designated for collection of non-biodegradable wastes which will result in automatic segregation at source. Putrescible portion of the wastes i.e. biodegradable fraction needs to be collected daily to prevent stench and maintain hygienic conditions at home, however, non-biodegradable wastes can be stored in homes for longer period without any significant discomfort or health issues.
4. Development of a buy back policy for recyclable items.
5. If community waste collection facilities are available then people can handover materials like discarded papers, corrugated paper boxes, plastic items, broken glasses, electronic items like used cell/batteries, broken cell phones, e-wastes etc. to such facility eventually preventing such items from reaching dumping yard and significantly reducing the volumes of wastes at landfill sites.
6. NGOs and local entrepreneur can be roped in to establish networks for channelization of recyclable materials; suitable incentives can be given to them to start up such enterprises.
7. During transportation it has to be ensured that wastes don't get mixed together.
8. MSWTF should have material recovery section wherein manual recovery of items like paper, glass, metals, plastics are carried out followed by segregation using density separating machines, size separation using trammel/screens.
9. Proper maintenance of the segregating machines is required.
10. Composting of wastes needs to be carried out by trained personnel so that the product meets the standard prescribed under the Municipal Solid Waste (M & H) Rules, 2000.

6. Plastic Waste Management

Plastics are non-biodegradable, synthetic polymers derived primarily from petro-fossil feedstock and made-up of long chain hydrocarbons with additives and can be moulded into finished products. Plastics have become the material of choice for a variety of applications because of following advantages:

i. The advantage to the manufacturer is that plastic products can be mass-produced and require less skilled staff.

ii. Plastics require little or no finishing, painting, polishing etc. Plastic is referred to as a self-finishing material. Particular finishes can be achieved at relatively low cost.

iii. Plastics can be easily printed, decorated or painted.

iv. Plastics are corrosion resistant, and generally waterproof although certain types of plastics can become brittle and it is possible for the sun's rays to cause the colour of the plastic to fade. It becomes bleached.

v. Plastics are lighter than metals, giving deeper sections for a given weight, and hence stronger sections.

The plastics industry's production process can be viewed in terms of adding value at each of the processing steps: from initial feedstock right through to the use of finished products by various markets. The process typically follows these steps:

i. Oil or natural gas is used as feedstock to produce monomers;

ii. Monomers are reacted into polymers;

iii. Plastic resins are then fabricated into useful products such as industrial parts, bottles and containers, films, fibres, etc.

iv. Finished products then serve market needs such as food packaging, electronics, automotive, medical products, etc.

The signature of all natural materials made by biological process is that they are biodegradable and bio-assimilable. The long life and desirability of plastics, which have made them, a material of choice for many applications is seemingly a disadvantage when it comes to their disposal. However, when handled properly, plastics do little damage to our environment. Plastics have the advantage that they can be easily reprocessed and recycled. The quantum of solid waste is ever increasing due to increase in population, development activities, changes in life style, and socio-economic conditions. In India, the per capita plastic consumption is 6-7 kg per annum as compared to the developed countries where, the per capita consumption is in the range of 15 to 22 kg/annum (CPCB study report 2009). It is estimated that approximately 15722 tonnes per day (TPD) of plastic waste is generated on the basis of per capita consumption based on population of India.

Plastics can be classified in many ways, but most commonly by their physical properties. Plastics may be classified also according to their chemical sources. The twenty or more known basic types fall into four general groups: Cellulose Plastics, Synthetic Resin Plastics, Protein Plastics and Natural Resins. Plastics, depending on their physical properties, may be classified as thermoplastic or thermosetting materials. Thermoplastic materials can be formed into desired shapes under heat and pressure and become solids on cooling. If they are subjected to the same conditions of heat and pressure, they can be remoulded. Thermosetting materials which once shaped cannot be softened /remoulded by the application of heat. The examples of some typical thermoplastic and thermosetting materials are tabulated in Table 1. Out of total uses of plastic, 80% are Thermoplastic and 20% are Thermosetting. The thermosetting plastics cannot be reused or recycled.

Table 1. Types of plastics

Sl.No.	Thermoplastic	Sl.No.	Thermosetting plastic
1.	Polyethylene Terepthalate (PET)	1.	Bakelite
2.	Polypropylene (PP)	2.	Epoxy
3.	Poly Vinyl Acetate (PVA)	3.	Melamine
4.	Poly Vinyl Chloride (PVC)	4.	Polyester
5.	Polystyrene (PS)	5.	Polyurethane
6.	Low Density Polyethylene (LDPE)	6.	Urea Formaldehyde
7.	High Density Polyethylene (HDPE)		

6.1 Plastic Waste Recycling

Post-consumer plastic recycling is still an emerging industry, and there is a wide range of products made from recycled plastic, including:

i. Polyethylene bin liners and carrier bags
ii. PVC sewer pipes, flooring and window frames
iii. Building insulation board
iv. Fencing and garden furniture
v. Garden sheds and composters
vi. Seed trays, jackets and fleeces
vii. Fibered sleeping bags and duvets, and a variety of office accessories
viii. Plastic lumber

While plastics can be recycled in commingled form to make plastic lumber products, separated resins have higher values and are preferred by most re-claimers. So it helps when handlers can sort plastics by resin type to meet that demand for higher value. The transformation of used plastic products into feed-stocks for manufacturing new plastic products is called reclamation. (The companies performing this function are more commonly referred to as plastic recyclers). But processing post-consumer plastic wastes is a more complex process, since the products are seldom as clean as virgin resins and often contains unknown residual contaminants. In the process of recycling, the material may lose its plastic property, so the recycling is almost restricted to 5-6 times. Beyond this it becomes a waste material (CPCB-Probes series).

Recycling of waste plastics is not the only solution for the post consumer plastic, as it remains in the environment after the third/fourth recycling process and ultimately unfit for reuse and hence it ends up in land filling. Hence recycling is not the complete solution for disposal of the waste plastics. The complete solution to the disposal of waste plastics is realized in the energy recovery and can be achieved in the blast furnace and in cement kiln by effectively utilizing the calorific value of plastics waste. The calorific value of plastic wastes can be utilized effectively by replacing coal. The use of plastic waste as alternative fuel will help to reduce the energy cost along with reduction in the CO_2 emissions. During co-incineration of plastic waste in blast furnace and cement kilns, it is completely burnt at high temperature and slag which remain as waste, can further utilized as cement and road construction. There is no risk of generation of toxic emission due to the burning of plastics waste in the process and the process is safe as per environmental norms (CPCB study report 2009).

6.1.1 Separation and Contamination Issues

When plastics are collected for recycling, they are not pure. They contain product residues, dirt, labels, and other materials and often contain more than one type of plastic resin, resins with different colors, additive packages, and so on. This contamination is one of the major stumbling blocks to increasing the recycling of plastic materials. Usefulness of the recovered plastic is greatly enhanced if it can be cleaned and purified. Therefore, technologies for cleaning and separating the materials are an important part of most plastics recycling systems.

6.1.2 Separation of Non-plastic Contaminants

Since most household plastics are collected for recycling mixed with other materials, the first step in processing is usually to separate the plastics from these other materials. Whether sorting is done, initial separation may simply separate plastics from non-plastics, with later separation by resin type, and sometimes by color as well, taking place in a dedicated plastics separation facility that receives mixed plastics from a number of MRFs (and likely from industrial facilities as well).

Inclusion of non-plastic contaminants in recycled resins can affect both processing of the material and performance of the products manufactured from these materials. Presence of remnants of paper labels, for example, can result in black specks in plastic bottles, detracting from their appearance and rendering them unsuitable for some applications. These paper fragments can also build up in the screens in the extruder during processing, resulting in greater operating pressures (and energy use) and requiring more frequent screen changes. The presence of solid inclusions in the polymer can adversely affect the physical performance of the moulded parts, resulting in premature failure. Mechanical properties can be decreased to the extent that thicker sections are required to obtain the desired performance.

6.1.3 Separation by Resin Type

In order to recycle plastics, they must be melted and then reshaped. However, there is a slight problem. When melted, one plastic does not mix with another type of plastic—this makes recycling difficult and separation necessary.

Contamination of one resin with another can also result in diminished performance. One of the most fundamental problems is that most polymers are mutually insoluble. Thus, a blend of resins is likely to consist, on a microscopic scale, of domains of one resin embedded in a matrix of the other resin. While this sometimes results in desirable properties, more often it does not. To further complicate matters, the actual morphology, and thus the performance, will be strongly dependent not only on the composition of the material but also on the processing conditions. Therefore, for most high-value applications, it is essential to separate plastics by resin type.

Another problem arises from differences in melting temperatures. When PET is contaminated with polyvinyl chloride (PVC), for example, the PVC decomposes at the PET melt temperatures, resulting in black flecks in the clear PET. A very small amount of PVC contamination can render useless a large quantity of recovered PET. On the other hand, at PVC processing temperatures, PET flakes fail to melt, resulting in solid inclusions in the PVC articles that can cause them to fail. Again, a small amount of PET contamination can render recovered PVC unusable.

6.2 Types of Plastics

Plastics recycling technologies have been historically divided into four general types - primary, secondary, tertiary and quaternary.

i. **Primary** recycling involves processing of a waste/scrap into a product with characteristics similar to those of original product.

ii. **Secondary** recycling involves processing of waste/scrap plastics into materials that have characteristics different from those of original plastics product.

iii. **Tertiary** recycling involves the production of basic chemicals and fuels from plastics waste/scrap as part of the municipal waste stream or as a segregated waste.

iv. **Quaternary** recycling retrieves the energy content of waste/scrap plastics by burning/incineration.

The confusion over what we can and cannot recycle continues to confound consumers. Plastics are especially troublesome, as different types of plastic require different processing to be reformulated and re-used as raw material. The plastic materials are categorized in seven types based on properties and applications. To make sorting and thus recycling easier, the universally accepted standards i.e. a resin identification code has been developed to help consumers identify and sort the main types of plastic. Plastic categorization code is shown in Table 2. It will also help in identifying whether the material used on the end product is virgin, recycled or a blend of virgin and recycled.

The symbol code we're familiar with—a single digit ranging from 1 to 7 and surrounded by a triangle of arrows—was designed by The Society of the Plastics Industry (SPI) in 1988 to allow consumers and recyclers to differentiate types of plastics while providing a uniform coding system for manufacturers.

6.2.1Easy Plastics to Recycle

The easiest and most common plastics to recycle are made of polyethylene terephthalate (PET) and are assigned the number 1. Examples include soda and water bottles, medicine containers, and many other common consumer product containers. Once it has been processed by a recycling facility, PET can become fibrefill for winter coats, sleeping bags and life jackets. It can also be used to make bean bags, rope, car bumpers, tennis ball felt, combs, cassette tapes, sails for boats, furniture and, of course, other plastic bottles.

Number 2 is reserved for high-density polyethylene plastics. These include heavier containers that hold laundry detergents and bleaches as well as milk, shampoo and motor oil. Plastic labelled with the number 2 is often recycled into toys, piping, plastic lumber and rope. Like plastic designated number 1, it is widely accepted at recycling centres.

6.2.2 Plastics Less Commonly Recycled

Polyvinyl chloride, commonly used in plastic pipes, shower curtains, medical tubing, vinyl dashboards, and even some baby bottle nipples, gets number 3. Like numbers 4 (wrapping films, grocery and sandwich bags, and other containers made of low-density polyethylene) and 5 (polypropylene containers used in Tupperware, among other products), few municipal recycling centres will accept it due to its very low rate of recyclability.

6.2.3 Another Useful Plastic to Recycle

Number 6 goes on polystyrene (Styrofoam) items such as coffee cups, disposable cutlery, meat trays, packing "peanuts" and insulation. It is less widely accepted and it can be reprocessed into many items, including cassette tapes, hangars and rigid foam insulation.

6.2.4 Hardest Plastics to Recycle

Last, but far from least, are items crafted from various combinations of the aforementioned plastics or from unique plastic formulations not commonly used. Usually imprinted with a number 7 or nothing at all, these plastics are the most difficult to recycle and, as such, are seldom collected or recycled. Tetrapacks, sachets for gutka, laminated packaging for chips etc. falls under this category.

Table 2. Plastic Categorization Code.

Symbol	Polymer Type	Example
♳	PET, Poly ethylene terepthalate	Fizzy drinks, mineral water bottles, cooking oils
♴	HDPE, High Density Polyethylene	Milk bottles, juice bottles, washing up liquid, grocery bags, Harpic bottles, recycling bins, agricultural pipe, base cups, car stops, playground equipment, and plastic lumber
♵	PVC, Polyvinyl Chloride	Pipe, fencing, shower curtains, lawn chairs, non-food bottles and children's toys, pipe and fittings
♶	LDPE Low Density Polyethylene	Plastic bags, various containers, dispensing bottles, wash bottles, tubing, and various moulded laboratory equipment

5	PP Polypropylene	Auto parts, industrial fibers, food containers, and dishware
6	PS Polystyrene	Desk accessories, cafeteria trays, plastic utensils, toys, video cassettes and cases, clamshell containers, packaging peanuts, and insulation board and other expanded polystyrene products (e.g., Styrofoam)
7	OTHER All other resins and multi-materials such as acrylic, nylon, polycarbonate, and polylactic acid (bio-plastic),and multilayer combinations of different plastics. Melamine, which is often used in plastic plates and cups. ABS (Acrylonitrile butadiene styrene, PPO (Polyphenylene oxide), PC (Polycarbonate), PBT (Poly butylene terepthalate)	Bottles, Headlight lenses, and safety shields/glasses. Tetra packs, laminated plastic packaging etc.

6.3 Plastic Recycling Process

Plastic recycling line for reclaiming waste plastics such as polyethylene bags, packaging films, buckets, crates etc. consists of crushing (size reduction), washing, drying, extrusion, melt filtering and pelletizing of the plastics as shown in Figure 3. Generally, it mainly includes following four steps.

a) **Collection** – The recycling facilities gather available recyclable plastic material in their area, such as from roadside collections, special recycling bins, or even directly from industries. In this way, both post-consumer and post-industrial plastic items are collected.

b) **Manual sorting** – All plastic items that are collected are then sorted according to the various plastic types indicated by the plastic recycling symbols and codes on them. Unwanted non-plastic materials found in the piles are promptly taken out.

c) **Chipping** – After sorting, the sorted plastic products are prepared for melting by being cut into small pieces. The plastic items are fed into a machine which has sets of blades that slice through the material and break the plastic into tiny bits.

d) **Washing** – At this step in the process of recycling plastic, all residue of products originally contained in the plastic items and various other 'contaminants' (e.g. paper labels, dirt) are removed. A particular wash solution consisting of an alkaline, cationic detergent and water are used to effectively get rid of all the contaminants on the plastic material, making sure that all the plastic bits are clean and ready for the final step.

During washing, the wash tank agitator serves as an abrasive, stripping the adhesive off any labels and shredding any paper mixed in with the plastics. The alkaline, cationic detergent (which is similar to the formulas used in shampoos and fabric softeners) is used to properly clean them, and effectively remove dirt and grease from the positively charged plastic surfaces.

e) **Pelleting** – The cleaned and chipped pieces of plastic are then melted down and put through a machine called an 'extruder' in this stage of the recycling plastic process. The extruder shapes the melted plastic into thin noodle-like tubes. The plastic tubes are then cut into small pellets by a set of rotating knives. The pellets are then ready to be reused and remade into new items.

The demand for recycled plastic products is increasing with the rising awareness of the need to recycle plastics. The value of plastic recycling is undeniable, because recycling cuts down on the need to send plastic waste to landfill. The process creates an avenue to reuse plastic, which is produced from petroleum, a non-renewable resource.Recycling plastic also helps to reduce pollution that arise from the plastic production process as well as the disposal of plastic through incineration and other means. Even though plastics undergo an extensive process to ensure they are as pure as possible, recycled plastics aren't as pure or consistent as they once were.

Figure 2. Plastic recycling process

Typically, post-consumer plastics are used for specific products, which rarely include food or beverage containers due to safety concerns. The reason being is that plastics are subject to absorbing chemicals during the recycling process or are not refined enough to go back into the food packaging stream.

6.4 Other emerging technology viz. Plastic Lumber & Polymer blended bitumen road.

The HDPE plastic waste is chopped up into small pieces called "flake" or "regrind" in shredding machine. The flakes are washed in water and soap and then dried. The flake is melted in a container as shown in Figure 3 and ready to be forced into the dye to make lumber.

The lumber is pushed out from the dye shown in Figure 4 at over 200 degrees Fahrenheit (93^0C). The lumber is pushed through a long trough of water to cool it before being cut into lengths. The lumber is cut to the length specified by the customer. A picnic table, deck, furniture and many other things can all be made from recycled plastic lumber.

The finished products have following advantages:

i. Moisture has no effect on this product, so it can sit out in the weather and not deteriorate.
ii. Nails cannot be easily driven into the lumber because of its density (similar to oak); therefore, drilling holes and using deck screws or carriage bolts is recommended.
iii. Plastic lumber does not require painting, will not splinter or crack, and is impermeable to insect attack.
iv. It can be used in virtually any application where wood lumber would be used, except for very high load bearing instances, and can withstand between five and six thousand pounds of pressure per square inch.
v. Additional products made from recycled HDPE include detergent bottles, recycling bins, backpacks and office products.

Figure 3. Container for melting of HDPE flake

6.5 Polymer blended bitumen road

The waste plastics are available in plenty. Use of these materials in flexible road construction can help in many ways like easy disposal of waste, better road construction, prevention of pollution and bitumen resource conservation. The laminated plastics contain two or more different polymers, PE & PET, PE & Aluminium. It is not easy to recycle these laminated materials and not collected by scrap collectors/ rag pickers.

Also, filmy materials made up of PE, PP, PS are also not collected and not viable/used for recycling purpose. Hence, such types of plastics are usually disposed along with the MSW. However, films, laminated films, foam and disposal cups can be used for road construction. Such materials have softening range between 130 to 150^{o}C with no evolution of gaseous products during heating at these temperatures. Hence, these materials can be used for road construction as it can be mixed with binders like bitumen to enhance the binding properties.

Figure 4. Recycling of HDPE into plastic lumber

The materials that can be used are:

i. Film having thickness <60micron.

ii. Disposable cups.

iii. Thermocole-EPS

iv. Laminated film made up of PE & PET.

v. Laminated film made up of PE & Aluminium.

vi. Bi-axially Polypropylene (BOPP) e.g. used in ball pen.

Films made up of PVC are not used for road construction, because of evolution of toxic gases like chlorine and HCl during heating. The process of manufacturing the mix (composite) using Mini Hot Mix plant is described below (Figure 5):

Step 1: Waste plastics, namely bags, cups and thermocole, made out of PE, PP &PS are collected and segregated. The dry segregated plastics are shredded into small pieces with size passing through 4.75mm sieves and retained in 2.36mm sieves.

Figure 5. Preparation of plastics-aggregate-bitumen mix & laying it on the road.

Step 2:

(a) The solid aggregate (granite, ceramic) is heated to around 170°C in the Mini Hot Mix plant and the heated materials are transferred to the adjacent puddling chamber.

(b) Simultaneously the Bitumen is heated to around 160°C.

Step 3: The heated aggregate is transferred to puddling chamber, where it is continuously stirred. The shredded plastic is sprayed on the heated aggregate to get a uniform coating at the surface of the aggregate. The quantity of addition of plastic depends on the nature of the surface to be prepared. The percentage addition can vary from 5 to 20% by weight to the weight of Bitumen. The added plastics gets softened and coated over the aggregate within 30 to 45 seconds, and the aggregate look like oily coated aggregate.

Step 4: The aggregate is coated with plastic waste. To this, Bitumen (160^{o}C) is added and mixed uniformly, maintain the temperature in the range of 155 to 165 ^{0}C which is very important. After mixing the material is withdrawn at around 140 ^{0}C and the polymer-bitumen mix (composite) can be used for road laying .