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Sustainable model of Plastic waste management

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Abstract: In India, Plastic waste rising rapidly day by day due to increasing the living standards of human beings by leaps & bounds and due to increasing population.The plastic waste management is not developing in India however, India having Plastic Waste (Management and Handling) Rules, 2011. The collection, transportation and process of plastic waste management are unscientific and chaotic. Uncontrolled dumping of wastes on outskirts of towns and cities has created abundantlandfills, which are not only impossible to reclaim because of the haphazard manner of dumping, but also have serious environmental implications in terms of ground water pollution and contribution to global warming. Burning of plastic waste leads to air pollution, which is equivalent to vehicular emissions at times.In the absence of plastic waste segregation practices, recycling has remained to be an informalsector working on outdated technology, but nevertheless flourishing owing to waste material availability and market demand of cheaper recycled products. Plastic recycling have been especially growing due to continuously increasing consumption levels of both the commodities.

In this paper,I developa model of plastic waste management under the rule and regulation which has been given by CPCB, Ministry of Environment and etc. in India to maintain the balance of the ecosystem by proper managing the plastic wastes.

Keywords: Plastic waste management; Recycling; Disposal; incineration; Plastic; India.

1. Introduction of Plastic

The increased use of plastics products as packaging application in the recent years has increased the quantity of plastics in the solid waste stream to a great extent. The quantum of solid waste is ever increasing due to increase in population, development activities, changes in life style, and socio-economic conditions. It is estimated that approximately 15722 tons per day (TPD) of plastic waste is generated on the basis of per capita consumption based on population of India.Plastic is the general term for a wide range of synthetic or semi synthetic polymerization products. They are composed of organic condensation or addition polymers and may contain other substances to improve performance or economics. There are few natural polymers generally considered to be "plastics". These polymers are broken in presence of suitable catalyst, into monomers such as ethylene, propylene, vinyl, styrene and benzene. These monomers are then chemically polymerized into different categories of plastics [1].

1.1 Waste Generation and Composition in India

The rate of waste generation in India is growing very quickly owing to urbanization and higher incomes. The current composition of waste carries a high potential for recycling that is barely exploited. Generally, about 15 percent of waste materials—which consist mainly of paper, plastic, metal, and glass—can be retrieved from the waste stream for further recycling (as shown in figure no. 1).Another 35 to 55 percent of waste material is organic waste, which can be converted into useful compost, leaving only 30 to 50 percent that needs to go to landfills [2].

Data pertaining to the physical and chemical composition of the MSW has been compiled for 75 cities from various renowned databases. An attempt has been made to establish a relation between the Calorific Value and the biodegradable and paper fractions of the MSW generated in various cities. The cities have been classified on the basis of population, i.e. cities having a population of over 20,00,000 are classified as Tier 1 cities, between 5,00,000 to 20,00,000 as Tier 2 cities, between 1,00,000 to 5,00,000 as Tier 3 cities and less than 1,00,000 as Tier 4 cities[3].

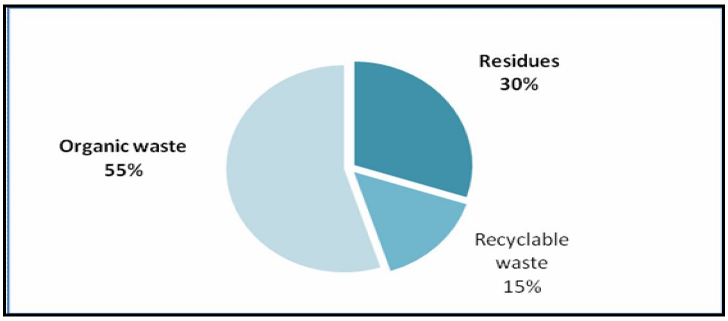

Figure no. 1 Recycling Potential

1.2 Description of Plastic Waste

Plastic products have become an integral part in our daily life as a basic need. It produced on a massive scale worldwide and its production crosses the 150 million tonnes per year globally. In India approximately 8 Million tonnes plastic products are consumed every year (2008). Its broad range of application in films, wrapping materials, shopping and garbage bags, fluid containers, clothing, toys, household and industrial products, and building materials. It is a fact that plastics will never degrade and remains on landscape for several years. Mostly, plastics are recyclable but recycled products are more hazardous to the environment than the virgin products. The recycling of a virgin plastic material can be done 2-3 times only, because after every recycling, the plastic material is deteriorated due to thermal pressure. Considering, 70% of plastic consumption is converted as waste, approximately 5.6 million tons per annum (TPA) plastic waste is generated in country, which equals to15342 tons per day (TPD) [1].

Plastic waste has a significant portion in total municipal solid waste (MSW). Hence, there is a formal system of waste collection in urban areas, however, informal sectors i.e. rag pickers, collect only value added plastics waste such as pet bottles etc. However, plastic carry bags and low quality plastic less than 20 micron do not figure in their priorities, because collecting them is not profitable. This is primarily because the rewards are not much than efforts required for collection, and this leads to plastic bags and other packaging materials continuing to pose a major threat to the environment [2].

Moreover the major concern for this waste stream is that these are non-biodegradable and remains in the environment for several years. Clogging of drains by plastic waste is a common problem. The packaging and poly vinyl chloride (PVC) pipe industry are growing at 16-18% per year. The demand of plastics goods is increasing from house hold use to industrial applications. It is growing at an annual rate of 22% annually. The polymers production has reached to 8.5 million tons in 2007.

1.3 Categories of plastics

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

As per BIS Classification, there are seven categories of plastics like; PET, HDPE, PVC, LDPE, PP, PS and other. The typical thermoplastic and thermosetting resins have shown in table no 1.

Table no. 1

S. No.	**Thermo plastic**	**S. No.**	**Thermoset Plastic**
1	Polyethylene Tetraphthalate (PET)	1	Bakelite
2	Polypropylene (PP)	2	Epoxy
3	Poly Vinyl Acetate (PVA)	3	Melamine
4	Poly Vinyl Chloride (PVC)	4	Polyester
5	Polystyrene	5	Polyurethane

6	Low Density Polyethylene (LDPE)	6	Urea-Formaldehyde
7	High Density Polyethylene (HDPE)		

1.4 Plastics Consumption in India

National plastic waste management task force in 1997 projected the polymers demand in the country. In India (Million Tones) documents the demand of different polymers in India during years 1995-96, 2001-02 and 2006-07. The comparison of demand and consumption from More than one fourth of the consumption in India is that of PVC which is being phased out in many countries. Poly bags and other plastic items except PET in particular have been a focus, because it has contributed to host of problems in India such as choked sewers, animal deaths and clogged soils [4].

2. Objective of the Study

The objectives of this study are in two fold.

i. To investigate the actual situation of plastic waste in India.
ii. To identify and propose future sustainable plastic waste management.

3. Plastic Materials

Plastics are man-made organic materials that are produced from oil and natural gas as raw materials. Plastics consist of large molecules (macromolecules), the building blocks of all materials. The molecular weights of plastics may vary from about 20,000 to 100,000 mg/L. Plastics can be regarded as long chains of beads in which the so-called monomers. Development of plastics production worldwide ethylene, propylene, styrene and vinyl chloride are linked together to form a chain called a polymer. Polymers such as polyethylene (PE), polystyrene (PS) and polyvinyl chloride (PVC) are the end products of the process of polymerization, in which the monomers are joined together. In many cases only one type of monomer is used to make the material, sometimes two or more. A wide range of products can be made by melting the basic plastic material in the form of pellets or powder [5]. Plastics can be either thermoplastics or thermosets, having melting which is given in table no. 2.

Table no.2 Melting point of common thermoplastic [7]

Polyolefin	**Melting point (^{0}C)**
LDPE	115
LLDPE	123
HDPE	130
Polyethylene (PE)	135
Polypropylene (PP)	170
Polystyrene (PS)	240
Polyethylene terephthalate (PET)	245
Polyamide 6 (PA6)	233

Materials that repeatedly often on heating and harden on cooling are known as thermoplastics. They can be melted down and made into new plastic end products. Thermo plastics are similar to paraffin wax. They are dense and hard at room temperature, become soft and mouldable when heated, dense and hard again and retain new shapes when cooled (see Figure 2 for a schematic overview of the structure of thermoplastic and Thermoset).

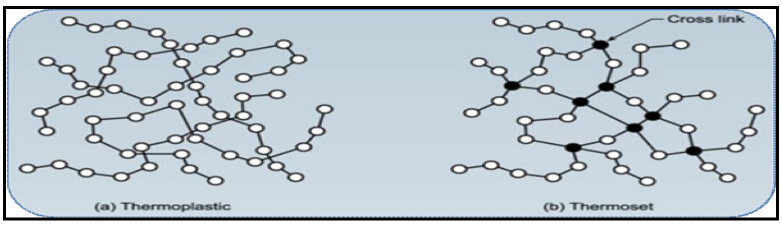

Figure no. 2. The structure of (a) thermoplastic and (b) thermosets

This process can be repeated numerous times and the chemical characteristics of the material do not change. In Europe, over 80% of the plastics produced are thermoplastics [5]. Thermosets, on the other hand are not suitable for repeated heat treatments because of their complex molecular structures (see Figure 2b).The structure of thermosetting materials resembles a kind of thinly meshed network that is formed during the initial production phase. Such materials cannot be reprocessed into new products unlike thermoplastics. Thermosets are widely used in electronics and automotive products. The properties of plastics can be modified by a number of substances known as additives.

3.1 Types of Plastics

In industrialized countries, literally hundreds of plastic materials are available commercially. In economically less developed countries however, fewer types of plastics tend to be used. In both economically less developed and industrialized countries, the four types of plastics that are most commonly reprocessed or recycled are polyethylene(PE), polypropylene (PP), polystyrene (PS)and polyvinyl chloride(PVC) as shown in Figure no3. Each of these can be subdivided according to their density, the type of process involved in their manufacture, and the additives they contain.

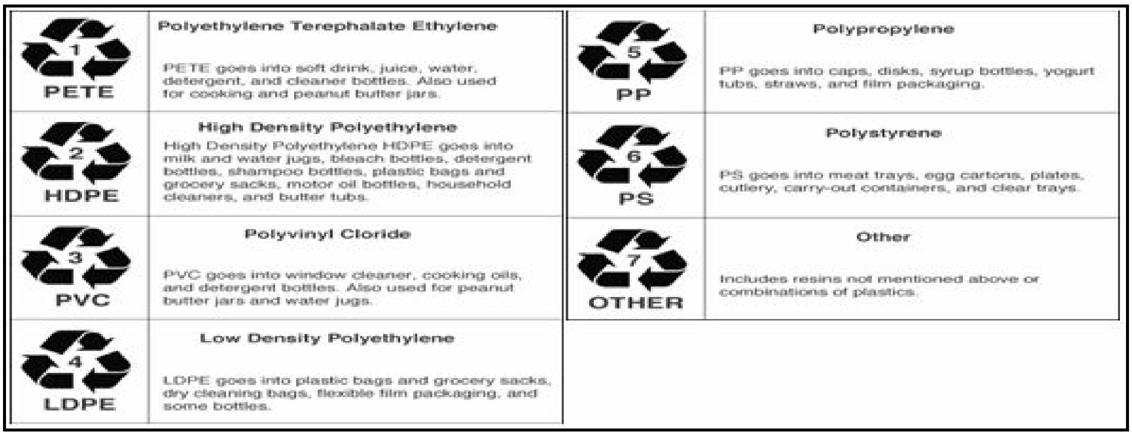

Figure no. 3.

3.2 Sources of Plastic

Plastics can be used for many purposes, and thus, waste plastics are generated from a wide variety of sources. The main sources of plastic waste can be classified as follows: industrial, commercial and municipal waste.

Table no. 3 Types of Plastics and variation in bending strength

Type of Plastic	Percentage of Plastic	Bending strength in Kg	Compression strength (Tonnes)
PE	10	325	250
	20	340	270
	25	350	290
Poly propylene	10	350	280
	20	370	290
	25	385	310
PS	10	200	155
	20	210	165
	25	215	170
PE foam	10	310	250
	20	325	265
	25	335	290
PP foam	10	340	270
	20	360	290

	25	365	270
Laminated plastic	10	360	290
	20	385	310
	25	400	335
BOPP	10	380	300
	20	400	310
	25	410	330

3.3 Industrial waste

Industrial waste and rejected material (so-called primary waste) can be obtained from large plastics processing, manufacturing and packaging industries. Most of this waste material has relatively good physical characteristics; i.e.it is sufficiently clean, since it is not mixed with other materials. It has been exposed to high temperatures during the manufacturing process which may have decreased its characteristics, but it has not been used in any product applications. Many industries discard polyethylene film wrapping that has been used to protect goods delivered to the factory. This is an excellent material for reprocessing, because it is usually relatively thick, free from impurities and in ample supply. Many industries may provide useful supplies of primary waste plastics:

- The automotive industries: spare-parts for cars, such as fan blades, seat coverings, battery containers and front grills.
- Construction and demolition companies: e.g. PVC pipes and fittings, tiles and sheets.
- Electrical and electronics industries: e.g. switch boxes, cable sheaths, cassette boxes, TV screens, etc.

Physical properties of waste plastics are given below in table no.4[8].

Table no. 4 Physical properties of waste plastics

Commercial Plastic material	**Nature of Plastic**	**Thickness (μ)**	**Softening point (^oC)**
Cup	PE	150	100-120
Carry bag	PE	10	100-120
Water bottle	PET	210	170-180
Cool drinks bottle	PET	210	170-180
Chocolate covers	Poly ester + PE + metalized polyester	20	155
Parcel cover	PE	50	100-120
Supari cover	Polyester + PE	60	120-135
Milk pouch	LDPE	60	100-120
Biscuit covers	Polyester + PE	40	170
Decoration papers	BOPP	100	110
Film	PE	50	120-130
Foam	PE	NA	100-110
Foam	PS	NA	110

Considerable amounts of waste plastics generated by many industries remain uncollected or end up at the municipal dump. Industries are often willing to cooperate with private collecting or reprocessing units.

3.4 Commercial waste

Workshops, craftsmen, shops, supermarkets and wholesalers may be able to provide reasonable quantities of waste plastics for recovery. A great deal of such waste is likely to be in the form of packaging material made of PE, either clean or contaminated. Hotels and restaurants are often sources of contaminated PE material.

3.5 Municipal waste

Waste plastics can be collected from residential areas (domestic or household waste), streets, parks, collection depots and waste dumps. In India, considerable amounts of plastic waste can be found within the Municipal Solid Waste stream due to the littering habit of the population. The most common type of plastic waste within the municipal waste stream is the "sachet" water film bags that are discarded in discriminately soon after consuming its contents. In Asian countries in particular, the collection of this type of waste is widespread. However, unless they are bought directly from households, before they have been mixed with other waste materials, such waste plastics are likely to be dirty and contaminated. Sometimes the plastics can be separated and cleaned quite easily, but contamination with hazardous waste is not always visible and may be more difficult to remove. Litter that has been waiting for collection for some time may have been degraded by sunlight. This is mainly a superficial effect, however, and does not always mean that the plastics cannot be reprocessed. The data on waste generated based on income with characterized of some Asian countries as given below in table no. 5[6].

Table no. 5 Data on waste generated based on income with characterized of some Asian countries

Countries	**GDP, PPP capita estimated for 2077 (USD)**	**Waste generation (Kg/capita/day)**	**Composition (% wet weight basis)**						
			Biodegradable	**Paper**	**Plastic**	**Glass**	**Metal**	**Textile/leather**	**Inert and others**
Hong kong	35,385	2.25	38	28	19	3	2	3	9
Japan	33,010	1.1	26	46	9	7	8	-	12
Singapore	31,165	1.1	44.4	28.3	11.8	4.1	4.8	-	6.6
Taiwan	31,040	0.667	31	26	22	7	4	9	-
South Korea	23,331	1.0	25	26	7	4	9	29	-
Malaysia	12,702	0.1-0.8	40	15	15	4	3	3	20
Thailand	9426	1.1	48.6	14.6	13.9	5.1	3.6	-	14.2
China	8854	0.8	35.8	3.7	3.8	2	0.3	-	47.5
Philippines	5409	0.3-0.7	41.6	19.5	13.8	1.3	4.8	-	17.9
Indonesia	5096	0.8-1	74	10	8	2	2	2	2
Sri Lanka	5047	0.2-0.9	76.4	10.6	5.7	1.3	1.3	-	4.7
India	3794	0.3-0.6	42	6	4	2	2	4	40
Vietnam	3502	0.55	58	4	5.6	1.6	1.5	1.8	27.5
Lao PDR	2260	0.7	54.3	3.3	7.8	1.5	3.8	-	22.5
Nepal	1760	0.2-0.5	80	7	2.5	3	0.5	-	7

3.6 Hazardous effects of Plastics

In terms of environmental and health effects it is important to differentiate between the various types of plastics. Most plastics are considered nontoxic (PVC is an important exception). Polyethylene (PE) and polypropylene (PP), for example, are inert materials [6], but it should be realized that plastics are not completely stable. Under the influence of light, heat or mechanical pressure they can decompose and release hazardous substances. For example, the monomers from which polymers are made may be released and may affect human health. Both styrene (which is used to make polystyrene, PS) and vinyl chloride (used to make PVC) are known to be toxic, and ethylene and propylene may also cause problems [7]. The environmental effects of plastics also differ according to the type and quantity of additives that have been used. Some flame retardants may pollute the environment (e.g. bromine emissions). Pigments or colorants may contain heavy metals that are highly toxic to humans, such as chromium(Cr), copper (Cu), cobalt (Co),selenium(Se), lead (Pb)and cadmium (Cd) are often used to produce brightly coloured plastics. Cadmium is used in red, yellow and orange pigments. In most industrialized countries these pigments have been banned by law. The additives used as heat stabilizers (i.e. chemical compounds that raise the temperature at which decomposition occurs), frequently contain heavy metals such as barium (Ba), tin (Sn), lead and cadmium, sometimes in combination.

4. Planning of Plastic Waste Management

Plastic Waste management involves activities associated with generation, storage, collection, transportation, processing and disposal. Plastic waste disposal in an environmentally sustainable manner should be achieved by adopting principles of economy, aesthetics, and energy conservation and pollution control. It encompasses planning, organization, administration, financial, legal and engineering aspects involving interdisciplinary relationships.

India as a developing country needs simpler, low cost technology keeping in view of maximum resource recovery in environmental friendly manner. An advanced technological solution for plastic waste disposal available in developed countries but cannot be directly adopted in developing countries due to difference in waste characteristics, financial constraints and socio-cultural aspects. With the aim of restrain littering and have proper disposal process for plastic waste, following activities are required to enforce in plastic waste management.

4.1 Two-Bin System

The plastic waste management needs to be optimized from concept to project management.

In order to follow appropriate plastic disposal technologies, segregation at source is essential. The recyclable waste material should be separated from food waste and other biodegradable waste, in a separate bin at the source of waste generation, by having a two bin system for waste storage. The bins are clearly labeled/marked on them "Recyclable Waste" and "Bio-degradable Waste". The plastic waste is separated out easily from other recyclable materials. The bio-degradable waste goes to the Municipal landfill for energy recovery or bio-fertilizer and recyclable waste can be handed over for further reuse. The reuse of recyclable waste material will reduce land fill requirement and environment pollution.

4.2 Porta cabin

Figure no. 4 Porta cabin for collection of all Plastic Waste

A Porta cabin is a collection facility most typically used for the collection of non-bottle waste plastics. There is usually a separate container for the collection of plastics, which are subsequently sorted into valuable and refuse fractions. For some polymers where cleanliness of the material is important for plastic polymers which may be collected separately. Large sized containers and disposal apertures permit the collection of bulkier goods such as furniture, pipes, windows etc. They also enable some degree of control to be exerted over the types of waste deposited. Porta cabins can be used for temporal or fixed deposits as shown in figure no 4.The collection schemes established for industrial and commercial sectors usually have better results than for the household waste and municipal waste (from retail, small business). There are two main reasons for this. Firstly, the waste is concentrated in a reduced number of places; this is in contrast to household waste arisings, which are geographically more dispersed, making collection more difficult. Secondly, wastes from industry are cleaner and better identified than wastes from households, which give a better value to this waste. Nevertheless, some professional sectors, like the agricultural or construction sectors, do generate quantities of films contaminated by such as earth, humidity etc.

4.3 Quality control

As already mentioned, the quality of the sorted plastics has a direct influence on its sale price. In order to maintain the desirable quality, routine quality control must be established. Samples of sorted materials should be analyzed in detail and the results compared with the requested quality.

This enables streams that have sorting deficiencies to be identified. A more detailed analysis will identify the cause of a bad sorting: misunderstanding of the sorting instruction, equipment failing etc. In order to maintain the desirable quality, routine quality control must be established. Samples of sorted materials should be analyzed in detail and the results compared with the requested quality. This enables streams that have sorting deficiencies to be identified. Reduction of volume and storing sorted waste plastics which can be bulky to transport and store. To make these activities more economical, some type of volume reduction process is necessary.

4.4 Baling

Baling is a suitable option for both films and bottles, providing a reduction in volume that aids storage and management of the waste plastics. The baler must be compatible with the baled materials and with the flow. Over-compaction may weld the waste together making it difficult to separate whilst under compacted bales will be unstable and difficult to stack. Most balers can be used for several materials, but adjustments may be necessary. The choice of baler strapping is also important; it must be strong enough to contain long-term baled material and particularly if the material is to be stored outdoors, be rust-resistant. Polyester strapping or stainless steel is commonly used. For plastic bottles, previous perforation of the bottles improves the density of the bales.

4.5 Pre-shredding

For the big pieces of waste plastics, such as pipes or window frames, pre-shredding can be an interesting option in order to reduce the stocking area and the transportation costs. However, it is the responsibility of the sorting plant to evaluate the benefits of such equipment in relation with its price. This type of equipment can also be helpful in reducing the volume of other waste. As for the baler, the two important points to check are the material compatibility and the outflow of materials to shred. It is important to note that shredded material, particularly mixed shredded plastics are not accepted by some markets because quality standards beyond common sorting processes are required and therefore assured applications for the shredded material should be investigated [10].

4.6 Storing sorted waste plastics

Rain does not affect the quality of plastics; however, UV light does degrade the physical and chemical structure of most plastics. The effect of UV degradation varies according to the virgin polymer, therefore if plastics are to be stored outside, they should be protected by tarpaulins or other UV-protective material. To avoid contamination by dust and dirt, plastics should be stored on clean concrete floors; storage of the material on pallets can also reduce contamination. Where plastics are to be stored indoors, fire-safety and prevention systems should be installed. Plastic is flammable and while it is difficult to ignite baled plastics; it is much easier for non-baled material. As such, these considerations must be integrated into the planning stages of storage areas.

4.7 Collection and transportation

The collection and transportation of plastic waste on a daily basis is an imperative step.Since the waste cannot be removed as fast as it is produced, it is stored and transported as soon as possible at specific pre-defined frequencies. The system of storage and types of vehicles are often compatible. Mechanical lifting bins are required to minimize the cost of manually collection.

5. Micro Planning

An efficient and cost beneficiary system of waste management requires micro planning for collection, storage, transportation processing and disposal of plastic waste. This should also ensure an effective participation of the Government, citizens and NGO's in planning and waste management system. This device reduces the volume of plastic waste by compacting, so that storage and transportation becomes relatively easier. Integrated sustainable waste manage model as shown in figure no. 5[9].

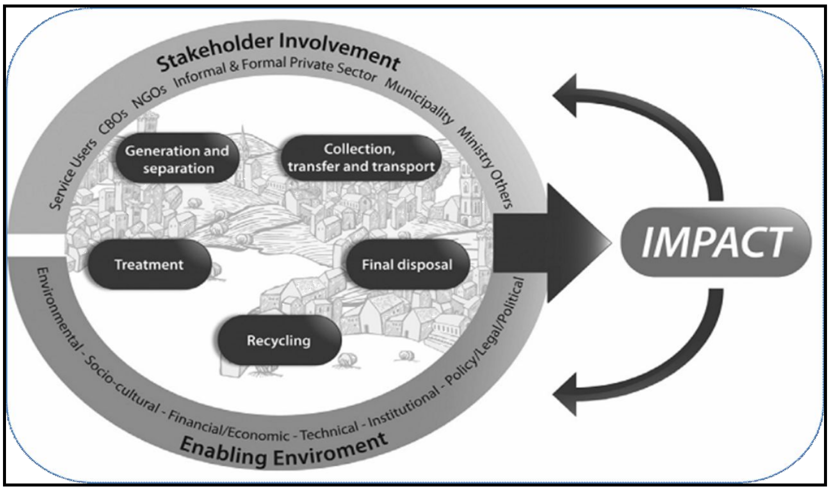

Figure no. 5The integrated sustainable waste management modal

6. Recycling of Plastic Waste

The recycling of plastic is possible through different methods. The compacted bales of plastic waste from stations and airport should reach the recycling unit on daily basis. Recycling of plastics waste should be carried with a view to:

- Minimize the pollution level during the process
- Enhance the efficiency of the process, and
- Conserve the energy

The practice of recycling post-manufacturing plastic waste has been in vogue since the last many years. But problems are encountered in case of post consumption of plastic. The incompatibilities of the components mixed are generally chemically different polymers and hence pose difficulties in processing. Many a time the in homogeneity of polymers will lead to inferior material properties. The collected plastic from any state of India has been channeled properly to recycle unit, but the multilayered metalized plastic which is littering the area is not recycled. This is because these wastes are not segregated anywhere in the channel of waste disposal and find its way in the landfill along with MSW. The selection of technological options to recycle/reuse of plastic wastes is depends upon the quality and quantity of waste. While determining the methodologies of recovery system, it is required to make a distinction between different recovery options namely: **Primary Recycling** (Conversion of waste plastic into products having performance level comparable to that of original products made from virgin plastics); **SecondaryRecycling** (Conversion of waste plastics into products having less demanding performance requirements than the original material); **Tertiary Recycling** (The process of producing chemicals/ fuels/ similar products from waste plastics); and **Quaternary Recycling** (The process of recovering energy from waste plastics by incineration). However, International Standards like ISO refers Plastics Recycling as a Recovery Process. The recovery has been divided into two categories namely material recovery and energy recovery.The process flow chart for recovery process is depicted in Figure no. 6.

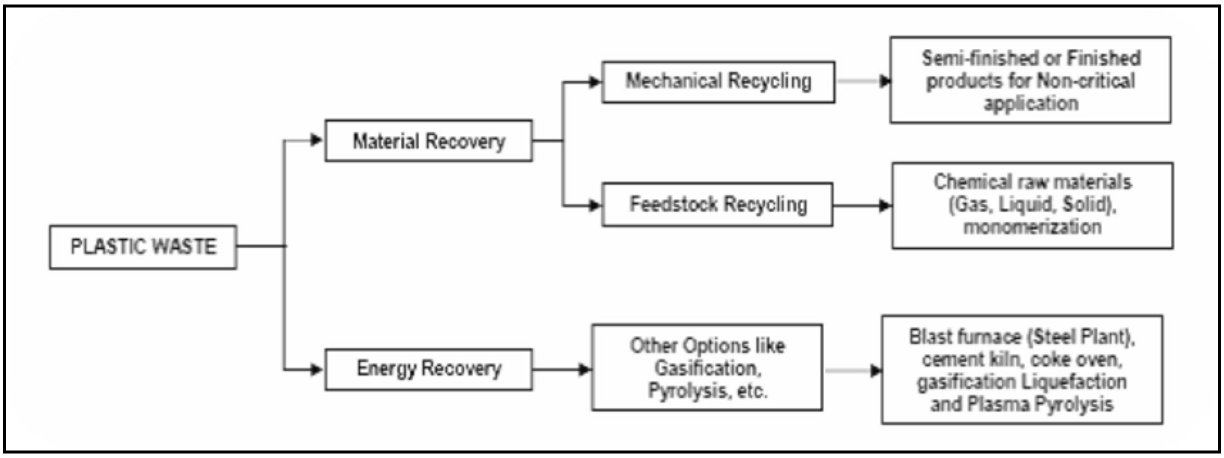

Figure no. 6 Schematic diagram of Plastic Recovery Options

6.1 Mechanical Recycling:

Mechanical recycling involves processing of waste in to a product with characteristics similar to those of original product. This is the most preferred and widely used recycling process due to its cost effectiveness and ease of conversion to useful products of daily use.

The limitation of this process is that the process requires homogenous and clean input. The process of mechanical recycling of waste plastics into products of varying usefulness mostly involves the essential steps namely:

- **Collection/ Segregation** (Plastic wastes are separated/segregated by Flotation Process in which varying density property of plastic waste is made use for segregating plastics);
- **Cleaning & Drying** (Post consumer plastic wastes require cleaning and drying than industrial waste. The wastes generated during these processes require proper treatment and disposal methods);
- **Sizing/ Chipping** (Cleaned plastic waste products should be sized/chipped to fed into the extruders for processing and palletizing and these operations depends upon the type and size of the plastic waste);
- **Agglomeration/Coloring** (Depending upon the end product, sized plastic waste is mixed with color master batch in high speed mixers/ agglomerators);
- **Extrusion/ Pelletisation**(Chipped plastics are plasticized and regranulated to make the plastic material ready for fabrication) and finally fabrication into End Product.

6.2 Technological Disposal Options

The selection of appropriate technology for plastic waste disposal and its processes for the management of plastic wastes are available in literature. Several processes and technologies have been explored and developed for plastic waste management. Some of these are:

- Chemical recycling of pet bottles into fibers
- Processing of plastic waste in Blast Furnace
- Co-incineration of plastic waste in cement kilns
- Utilization of plastic waste in road construction with bitumen
- Plasma Pyrolysis Technology for disposal of plastic waste and
- Gasification

6.3 Chemical recycling of pet bottles into fibers

This method of plastic recycling, involves the breaking down of polymer chain in to their basic components, which can then be used in various industries. The feedstock plastic recycling process is flexible and more forbearing to the plastic additives, as compared to the mechanical plastic recycling. This is the most costly method of recycling. The varying end products are obtained by using following process:

6.3.1 Monomerization:

The waste plastics are initially broken down into their constituent monomers by chemical reaction (depolymerization). These monomers are then extracted for use as the raw material in new plastic products. Monomerization produces higher quality plastic raw materials than material recycling. Which in turn enables the production of high quality plastic products with the same (or almost the same) quality as virgin raw material.

Among other products, this enables the recycling of waste PET bottles into new PET bottles, which is not possible with other recycling technologies. About 50% recovery is possible through this process. The limitations of this process is that, the large scale process setup along with clean and single resin plastic waste as input is required.

6.4 Processing of plastic waste in Blast Furnace:

Plastic waste can be co-incinerated as fuel in the iron and steel industry. This will reduce coal consumption and hence in reduction in the consumption of energy. The proportion of waste plastic added to coal should be about 1% by mass. Increased addition of waste plastic will reduce the heating strength of the coal/coke. The use of plastic in coke ovens-a typical high-temperature process in the iron and steel industry was put in practice in the year

2000 at Nippon Steel Corporation, Japan. In this process, the collected and baled plastic waste that has been agglomerated by pre-treatment is mixed together with coal and charged into coke oven. The mixed plastic waste and coal are carbonized in an oxygen-free reducing atmosphere at about 1,100 to 1,200^{0}C. As a result, the waste plastic is thermally decomposed into coke (about 20%), tar/light oil (about 40%) and coke oven gas (about 40%). These products obtained by the carbonization of waste plastics have their own uses.When plastics are used together with coke, CO_2 emission is significantly less. The excessive reducing gases are also used for blast furnace stove and power generation.

6.4.1Blast Furnace:

Plastics waste can be used as an alternative raw material in blast furnaces to generate energy for manufacturing of iron. Plastic waste can be successfully used as a reducing agent in blast furnaces for the manufacturing of iron from its ore. Use of coke in blast furnace provides only one type of reducing agent- carbon Monoxide. In contrast, use of plastic waste provides one additional type of reducing agent – Hydrogen. Advantage of this process includes use of all types of plastics including laminated plastics without creating any environmental pollution. The high temperature inside the blast furnace around 2000^{0}C ensures that there is no possibility of any dioxins formation even if PVC is processed.Furthermore, as the reducing atmosphere in the low- temperature region at the top of the furnace contains no oxygen, no dioxins are produced or re-synthesized in the lower temperature zone also.The plastics waste is first formed into suitable size either by crushing or pellatising as necessary, and subsequently injected into the blast furnace from the tuyeres at the base of the furnace with hot air. The injected plastic waste material is broken down to form reducer gas- Carbon Monoxide (CO) and Hydrogen (H_2). The reducer gas rises through the raw material layers in the blast furnace and reacts with iron ore to produce pig iron. The gas, after the reduction reaction, is recovered at the top of the blast furnace which has energy content to the tune of 800 kcal/NM3 and is reused as a fuel gas in heating furnaces within the steel plant.

6.5Co-incineration of Plastics Waste in Cement Kilns:

Keeping in view the problems associated with the disposal of plastic waste, CPCB initiated a study on “Co-incineration of plastic waste in cement kiln” in collaboration with Indian Centre for Plastics in the Environment (ICPE), MP Pollution Control Board and ACC Ltd. Co-incineration refers to the usage of waste materials as alternative fuels to recover energy and material value from them. The temperature in the cement kiln process is about 1400^{0}C.Excess level of oxygen and counter flow operation with the flue gases moving in a direction opposite to the materials lends a high degree of turbulence to the process. The presence of an alkaline reducing environment (lime) and the pre-heating of the raw materials by a preheated tower (>100 meter tall) acts as an ideal scrubber for hot flue gases before they are emitted into the atmosphere. The 3Ts- Time, Temperature and Turbulence in cement kilns provides extremely high destruction removal efficiency (DRE) for the plastic wastes. Co-incineration leaves no residue as the incombustible, inorganic content of the waste materials are incorporated in the clinker matrix. Therefore, after the waste is co-incinerated, it becomes a part of the product. Co-incineration ranks higher on the waste disposal hierarchy and eliminates the need for landfills and incineration.

6.6Utilization of plastic waste in road construction:

To address the plastics waste disposal issue, an attempt has been made to describe the possibilities of reusing the plastics waste (post-consumer plastics waste) in road construction. Central Pollution Control Board (CPCB) Delhi has published “Indicative Operational Guidelines on Construction of Polymer – Bitumen Roads for reuse of waste plastics (PROBES/101/2005-06). The document explains the method of collection, cleaning process, shredding, sieving and then mixing with bitumen for road laying. By using this technology (plastics waste coated aggregate bitumen mix), several roads have been laid in the States of Tamil Nadu, Maharashtra, Pondicherry, Kerala,Andhra Pradesh and Goa. To evaluate the performance of the built roads using plastics waste coated aggregate (PCA) bitumen mix and also to generate data base for evolving Standards by Indian Road Congress (IRC), CPCB has instituted a study on “Performance Studies ofPolymer Coated Bitumen Built Roads during 2002-2007” to Thigarajarcollege of Engineering, Madurai.

6.7Plasma Pyrolysis Technology (PPT):

Plasma pyrolysis is a state of the art technology, which integrates the thermo-chemical properties of plasma with the pyrolysis process. The intense and versatile heat generation capabilities of Plasma Pyrolysis technology enable it to dispose of all types of plastic wasteincluding polymeric, biomedical and hazardous waste in a safe and reliable manner. Plasma Pyrolysis is the thermal disintegration of carbonaceous material in oxygen-starved atmosphere. When optimized, the most likely compounds formed are methane, carbon monoxide, hydrogen carbon dioxide and water molecules.

6.7.1 Process Technology:

In Plasma Pyrolysis, the plastics waste is fed in to primary chamber at 850°C through a feeder. The waste material dissociates into carbon monoxide, hydrogen, methane, higher hydrocarbons etc. Induced draft fan drains the pyrolysis gases as well as plastic waste into the secondary chamber where these gases are combusted in the presence of excess air. The inflammable gases are ignited with high voltage spark. The secondary chamber temperature is maintained at 1050°C. The hydrocarbon, CO and hydrogen are combusted into safe carbon dioxide and water. The process conditions are maintained such that it eliminates the possibility of formation of toxic dioxins and furans molecules (in case of chlorinated waste). The conversion of organic waste into non toxic gases (CO_2, H_2O) is more than 99%. The extreme conditions of plasma kill stable bacteria such as bacillus sterio- thermophilus and bacillus subtilis immediately. Segregation of waste is not necessary, as the very high temperatures ensure treatment of all types of waste without discrimination [12].

6.8 Gasification:

Gasification is a recycling method where waste plastics are processed into gases such as carbon monoxide, hydrogen and hydrogen chloride. These gases are then used as the chemical raw material for the production of chemicals such as methanol and ammonia.Almost all types of plastics, including those containing chlorine, can be recycled under the gasification method. This method is therefore suitable for miscellaneous plastics or plastics that are hard to sort.

In this process, the long polymer chains are broken down into small molecules, for example, into synthesis gas. The process may be fixed bed or fluidized bed gasification. In the fluidized process sand is heated to 600~800°C at first- stage low temperature gasification furnace and plastic introduced into the furnace. Waste plastic break down on contact with the sand to form hydrocarbon, carbon monoxide and hydrogen. The gas from the low-stage gasification furnace is allowed to pass in second-stage high temperature gasification furnace with a steam at a temperature of 1,300~1,500°C to produce a gas composed primarily of carbon monoxide and hydrogen. At the furnace outlet, the gas is rapidly cooled to below 200°C to prevent the formation of dioxins. The gas then passes through a gas scrubber, and any remaining hydrogen chloride is neutralized by alkalis and removed from synthetic gas [12].Slag is produced as a by-product, which can be utilized as raw material for civil engineering works and construction materials. There are problems in controlling the combustion temperature and the quantity of unburned gases. The current status of plastic waste management is in given below table no.6.

Table no. 6 Status of Plastic waste management (Updated on 30-05-2012)

S. No	Items	Description	
1	**Total Population 2008 (As per-World Bank)**	1139964932 (Say 114 Million)	
2	**Estimated Plastic Production in 2008**	8 Million tons	
3	**Plastic Waste Generation**	**Per Year**	**Per Day**
	(Considering;70% as waste)	5.6 Million tons/Year	15342.46 tons/day
4	**Plastic Waste Generation**	**Per Year**	**Per Day**
	per capita.	4.91 kg/Year	13.45 gm/day
5	**Plastic Waste Collection**	**Per Year**	**Per Day**
	(Estimated;60% by weight	3.36 Million tons/Year	9205 tons/day
6	**Uncollected Plastic Waste**	**Per Year**	**Per Day**
	(Estimated;40% by weight	2.24 Million tons/Year	6137 tons/day
7	**a) CPCB study on MSW Generation**	**Per Year**	**Per Day**
	in 60 major cities (2010-11)	1,8466080 Million tons/Year	50592 tons/day
	b) CPCB study on Plastic waste	**Per Year**	**Per Day**
	generation in 60 major cities (2010-11)	0.1277847 Million tons/Year	3501 tons/day
8	**No. of Plastic Manufacturer and Recycling unit in industrial area**	5511 (30 States and UTs)	
9	**No. of Registration Granted**	2108	
10	**No. of States and UTs issued**	15 (Goa, Haryana, Himachal Pradesh, Karnataka, Kerala Maharashtra,	
	Separate Act/Notification	Madhya Pradesh , Nagaland, Punjab, Meghalaya, Chandigarh,	
		Lakshadweep Pondicherry, Delhi, Rajasthan)	
11	**Name of states and UTs Ban Plastics Carry Bags**	**Detail given as below**	
12	**i) Complete Ban**	11 (Chandigarh, Sikkim, Nagaland, Delhi, Haryana, Himachal Pradesh,	
	(Through Notification/Act)	Tripura, Rajasthan, J&K, Andaman & Nicobar island & Lakshadweep)	
	ii) Partial Ban	10 (Andhra Pradesh, Arunachal Pradesh, Assam, Goa, Karnataka,	
	(Through Executive Order	Orissa, Tamil Nadu, West Bengal, Mizoram, Uttar Pradesh	
13	**Names of States and Uts Increased the**	03 (Maharashtra:50, Tamil Nadu:60 μ and Puducherry:51 μ	
	thickness of plastic carry bags i.e>40 μ		
14	**Plastic Waste Utilization**	i) Plastic waste can be utilized in road construction such as in the states of	
		Tamil Nadu, Karnataka, Maharashtra ,Pondicherry and Himachal Pradesh etc.	
		ii) Plastic waste can be co-processed in cement kilns such as in the states	
		of Madhya Pradesh, Tamil Nadu , Orissa, Andhra Pradesh etc.	
15	**Use of carry bags made from**	As per Plastic Waste (Management & Handling) (Amendment) Rules,2011	
	Compostable plastic or material	carry bags can be made from compostable plastic or material confirming	
		IS/ISO ; 17088 :2008	

7. Assessment and Quantification of Plastic Waste Quantification in Sixty Cities

CPCB has sponsored a study to CIPET for Assessment and Quantification of Plastic Waste generation in sixty major cities. The preliminary findings of the study are in given below;

Table no. 7

City	TMSW	PMSW	Total Plastic Waste (TPD)
Kavaratti	2	12.16	0.24
Dwaraka	18	8.28	1.49
Daman	25	4.554	1.14
Panjim	25	4.47	1.12
Gangtok	26	11.12	2.89
Jamshedpur	28	3.216	0.90
Silvassa	35	6.077	2.13
Port Blair	45	10.76	4.84
Kohima	45	5.013	2.26
Shimla	50	4.273	2.14
Meerut	52	6.444	3.35
Gadhinagar	97	4.361	4.23
Shilong	97	5.436	5.27
Itanagar	102	5.352	5.46
Agartala	102	5.712	5.83
Aizwal	107	7.948	8.50
Imphal	120	5.132	6.16
Ranchi	140	5.915	8.28
Kochin	150	6.288	9.43
Dhanbad	150	5.008	7.51
Guwahati	204	5.036	10.27
Asansol	210	6.017	12.64
Dehradun	220	6.665	14.66
Patna	220	5.696	12.53
Raipur	224	10.607	23.76
Rajkot	230	6.92	15.92
Tiruvanandapuram	250	6.022	15.06
Pondicherry	250	10.62	26.55
Chandigarh	264	3.098	8.18
Jammu	300	7.226	21.68
Jaipur	310	5.085	15.76
Vishakapattnam	334	9.033	30.17
Nashik	350	5.822	20.38
Bhopal	350	6.594	23.08
Allahabad	350	5.377	18.82
Jabalpur	400	5.175	20.70
Bhubaneswar	400	7.862	31.45
Madurai	450	5.059	22.77
Varanasi	450	5.78	26.01
Agra	520	7.863	40.89
Srinagar	550	5.117	28.14
Amritsar	550	4.44	24.42
Vadodara	600	4.704	28.22
Vijayawada	600	7.352	44.11
Nagpur	650	6.984	45.40
Coimbatore	700	9.473	66.31
Faridabad	700	11.65	81.55
Indore	720	8.805	63.40

Ludhiana	850	5.962	50.68
Surat	1200	12.468	149.62
Lucknow	1200	5.886	70.63
Pune	1300	7.971	103.62
Kanpur	1600	6.666	106.66
Bangalore	1700	8.483	144.21
Ahmedabad	2300	10.5	241.50
Kolkata	3670	11.59	425.35
Hyderabad	4200	4.72	198.24
Chennai	4500	9.54	429.30
Mumbai	6500	6.477	421.01
Delhi	6800	10.13	688.84

The total MSW Generated in 60 cities as shown in table no. 7, around 48592 MT/Day and the Total Plastic Waste generated in same cites around 3905.64 MT/Day.

8. Plastics recycling & sustainable development

The recycling of plastic waste can be a positive contribution to a sustainable development policy, integrating environmental, economic and social aspects, within a framework of effective legislative instruments. Continuing advances in sorting and processing technologies is increasing the accessibility of waste previously deemed unsuitable for recycling. Greater ranges of materials are now accepted for recycling; while developments in collection and sorting systems continue to increase the quality of recycle waste generated. This is supported by R&D into new markets for secondary plastics, which is essential if plastics' recycling is to be sustainable. Research into new and existing practices will expand opportunities for secondary materials; what is currently not technically or economically viable may be so in the future. It should look towards the material needs of the present, using best available technologies and practices to meet market demands, while appreciating the impacts that future technological and material quality requirements will have on current practice [10].

The benefits of recycling can be categorized into these aspects such as; environmental, economic and social and Environmental awareness of the population. These are briefly explained below.

8.1 Environmental aspects

There is only one environment and it must be treated with the respect it deserves already been extracted then it makes sense to use them again if possible. This means that reserves last longer into the future. Moreover, recycling of plastic waste conserves natural resources, particularly raw materials such as oil and energy. The more that is recycled, the longer will natural resources be available for future generations. It means that there is less environmental impact due to mining, quarrying, oil and gas drilling, deforestation and the likes. If there are fewer of these operations, the environment will be safe from continuous destruction and degradation.

Another positive effect of recycling on the environment is that it may reduce emissions of substance such as carbon dioxide (CO_2) into the atmosphere. From life- cycle analysis of reprocessed plastics and virgin plastics, it is known that the emissions of CO_2, SO_2, NO_X (NO and NO_2) are much smaller for recycled plastics compared to that for virgin materials [13]. Hence the environment will be better safe from air pollution and global warming if recycling is adopted on large scales. Recycling of plastic wastes will also safe both ground and surface waters from pollution. This is because if discarded randomly, they choke gutters and even find their way into water bodies that serve as sources of drinking water for communities and towns. They also help to breed leachate that can seep into the ground there by contaminating groundwater bodies as well.

8.2 Economic aspects

Resource recovery reduces the quantity of raw material seeded in production processes. The reuse of plastic say therefore helps to reduce the dependence on ported raw materials and to save foreign currency. Due to increasing cost of virgin plastics as a result of dwindling oil reserves, the use of reprocessed pellets for product manufacture will save recycling companies from folding up as a result of high cost of importation of virgin pellets. The low energy and water consumption will save recycling companies from paying huge bills that could otherwise have adverse effect on their operations [10].

8.2.1 Creating employment

Recycling can be an opportunity to create local jobs in collection, sorting, communications, administration and reprocessing. The reprocessing can be undertaken locally, regionally or beyond, and consequently the positive economic aspects of increased employment can be local or dispersed further afield. Job creation obviously brings many positive social effects.

8.3 Social aspects

The introduction of an intensive recycling strategy can avoid the need of new or additional incineration or landfill capacity. The setting up of such facilities is a challenge for the public authorities, which will inevitably face some degree of Nimby phenomenon, although this can be mitigated through effective, sustained public communications. However, in many cases recycling costs are higher than incineration; hence the cost for the citizen will go up.

Recycling of plastic wastes helps to keep the environment clean. Therefore diseases associated with filth will be prevented and this will save foreign exchange in the importation of drugs to fight cholera and malaria that may result from the rubbish heaps. Recycling will also create a healthy environment for tourists attraction Recycling is a source of job creation. Through recycling, numerous poor people will get employed particularly at the collection stage and hence be able to earn their living. This will help raise social standards and to eliminate vices in society.

8.4 *Environmental awareness of the population*

The introduction of recycling programmes will heighten public environmental awareness. As a consequence, a significant fraction of population feels motivated to participate in schemes where they are offered. There often follows an increased demand – with local elected representatives targeted - to improve and extend the existing services to a wider variety of waste plastics. This enhanced awareness can be linked beneficially to plastics in general, improving the image of these materials (which are often associated with wastage, the throw-away society and litter). In addition, including plastics in multi-material collection schemes can raise the overall amount of materials collected from curbside collection schemes by between 20 – 30 per cent.

9. Zero Waste Concepts

Humanity has to evolve to Zero Waste Management system for sustainability. How long and where all can we keep dumping our waste or keep releasing in air and water when it is very much possible to process every waste - solid liquid or in gaseous form in a way so to render it harmless to the nature, why are we not doing it and whenever it is difficult, the technology development for it, is not only possible, but is within our means to do so, then why don't we do it. We should work together in this direction: The climate crime update series is for sharing information on these issues.

Total recycling of waste i.e. of every useful product at the end of its usable life, and useless by products of its production process, may it be in gaseous, liquid or solid form or their combinations, should be given back to the nature in the naturally harmless forms. In 1962 it took 0.7 years for the earth's annual biological harvest to regenerate and now it takes 1.25 years [14]. Global ecosystem services have been over-used significantly in parallel with world economic growth. Global economic growth has increased 5 times since the mid-twentieth century and 60% of the world's ecosystem services have been degraded during the same period [15]. It is estimated that by 2050 we will have 9 billion people on earth. Global non-renewable resources are depleted as a result of over consumption. Continuous depletion of natural finite resources by urban populations is leading to an uncertain future. Therefore, to prevent further depletion of global resources, we need sustainable consumption and strategic Plastic waste management systems based on (i) waste avoidance, (ii) material efficiency and (iii) resource recovery [16].

Waste is the symbol of inefficiency of any modern society and a representation of misallocated resources. More than 50% of the world's population live in urban areas [17], and some estimates have suggested that 80% of the human population will dwell in urban areas by 2030. Cities cover only around 2% of the world's surface consume over 75% of the world's natural resources and generate 70% of all the waste produced globally [18-19]. Creation of any waste depletes natural resources, uses energy and water, places pressure on land, pollutes the environment and, finally, creates an additional economic cost for managing the waste. We need to move to a position where there will be no such thing as waste, merely transformation; this position is called **zero waste**.'Zero waste' is one of the most visionary concepts for solving waste problems. Many cities around the globe such as Adelaide, San Francisco and Stockholm have declared their zero waste vision and these cities are working to be the world's first zero waste city. But how to transform our existing cities into zero waste cities and how to measure the performance of a zero waste city are the prime questions to answer in zero waste research. The products that we consume every day are primarily produced using virgin materials, energy and water. From resources extraction to waste generation, consumption depletes the environment by contributing greenhouse gases (GHG) to the atmosphere.

8.1 Development of the zero waste concepts

From outer space to the bottom of the ocean, generations of waste is accumulating over time. On one hand, the estimated amount of debris put into space by humans and no longer in function has increased from 14,000 pieces in 2007 to 18,000 pieces in 2008. On the other hand, accumulation of waste in the great Pacific Garbage Patch (currently 1,760,000 sqkm, 12 times bigger than Bangladesh) is getting larger every day [20 – 21]. Currently, the world's cities generate about 1.3 billion tonnes of solid waste per year and the volume is expected to increase to 2.2 billion tonnes by 2025 [22]. Waste generation rates will more than double over the next twenty years in lower income countries. However, this current trend of generating waste is not a recent practice; it comes from the very early stages of modern society.

Zero waste means designing and managing products and processes systematically to avoid and eliminate waste, and to recover all resources from the waste stream [23]. Working towards zero waste has become a worldwide movement that motivates changes in design that make it possible to disassemble and recycle products. To put it simply, zero waste means no unnecessary and unwanted waste from a product at any stage of its life cycle. The scope of zero waste comprises many concepts that have been developed for sustainable waste management systems, including avoiding, reducing, reusing, redesigning, regenerating, recycling, repairing, remanufacturing, reselling and re-distributing waste resources. Hence, a zero-waste strategy is growing in popularity as best practice. It not only encourages recycling of products but also aims to restructure their design, production and distribution to prevent waste emerging in the first place [24].Most modern societies have been implementing integrated waste management systems to recycle and recover resources from waste. However, the concept of zero waste is not limited to optimum recycling or resource recovery; in addition to that zero waste requires elimination of unnecessary waste creation at the first stage of designing a product. Therefore, zero waste design principles go beyond recycling to focus firstly on avoidance and reduction of waste by innovative product design and then recycling and composting the rest [25] and the drivers for transforming current cites into waste cities shown in figure no. 7.

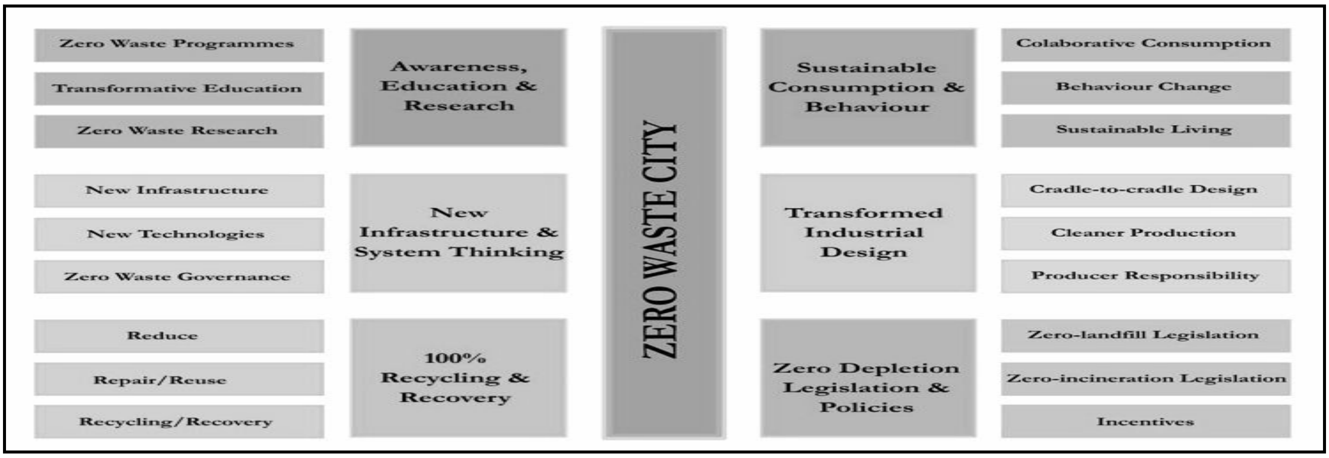

Figure no. 7 Drivers for transforming current cities into zero waste cities.

With proper implementation of all these principles, current cities could be transformed into zero waste cities. The key drivers are based on short-term and long-term implementation strategies. Awareness and education, behavior change and systems thinking are long-term strategies, whereas innovative industrial design, legislation and 100% recycling are the short-term strategies to implement in a city.

One of the important aspects of the zero waste cities is the conversion of the linear city metabolism to a circular city metabolism. This transformation requires a series of holistic strategies based on key development principles. Education and research is on the top of the zero waste hierarchy. Without proper environmental awareness and advanced research on waste, it would not be possible to achieve zero waste goals. Sustainable consumption and behavior is placed second in the zero waste hierarchy. As the current trend of consumption is unsustainable and cannot be continued for ever, it is important to understand the reality and act accordingly. The next on zero waste hierarchy is transformed industrial design for example, cradle-to-cradle design, eco-design or cleaner production combined with extended producer responsibility. It is important to have specific zero depletion legislation and incentive policies as part of the strict environmental legislations. If products are designed in such a way that everything can be recycled, then achieving optimum recycling and resource recovery will not be impossible in the long run.

In a zero waste city material flow is circular, which means the same materials are used again and again until the optimum level of consumption. No materials are wasted or under used in circular cities. Therefore, at the end of their lives products are reused, repaired sold or redistributed within the system. If reuse or repair is not possible then they are recycled or recovered from the waste stream and used as inputs, substituting the demand for the extraction of natural resources.

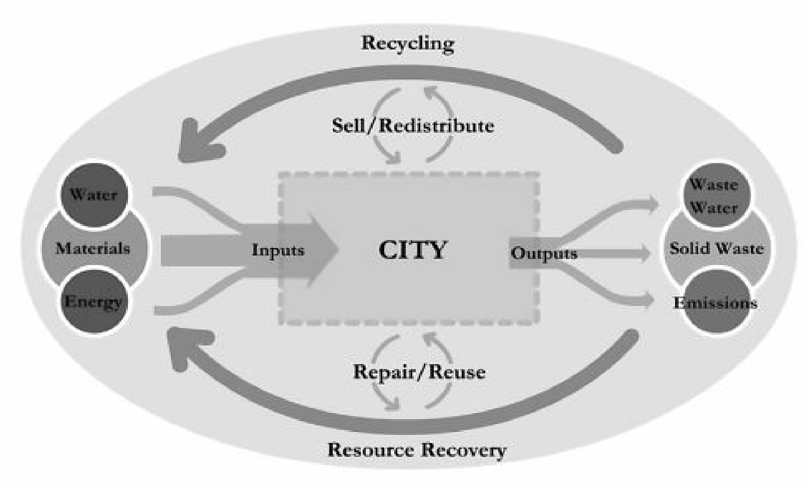

Figure no. 8 Material flow in a Zero waste city

Figure no.8 shows the symbolic material flow of a circular city, where the end of-life product or output waste are treated as resources and used as inputs in the city's metabolism.From this Figure no.8, it is clear that a city's performance is reflected by its waste management systems. Material flow in a zero waste city should be circular and resources should be used efficiently. The performance of waste management systems therefore symbolizes the performance of a zero waste city. Hence, it is important to development a zero waste measurement tool for cities. Finally, a new system thinking approach and innovative technologies are needed to transform current cities into zero waste cities.

10. Conclusions

There are no independent management systems for plastic waste. They come under the larger purview of solid waste management with Municipal Corporation's being the key organization responsible for it. Management of solid waste including plastic waste is in miserable states in India. Due to lack of proper collection systems, the waste generated in the city is littered at public places leading to unhygienic conditions. Lack of segregation of waste at source or at collection points is creating problems for management of waste.

To support any recycling initiative, storage of plastic waste will be a problem due to its high volume but less density. However, if there are systems in place for segregation and storage of plastic waste at Porta- cabin collection points, there are technologies available for compacting the waste for easy and economical storage and transportation without compromising the quality of plastic and then recycling all sorted plastic waste based on zero waste mechanism.

The major legislations governing solid plastic waste management are in India such as;

- Municipal Solid Waste (Management and Handing) Rules, 2000
- Recycled Plastic Manufacture and Usage (Amendment) Rules, 2003

- Plastic Waste (Management and Handling) Rules, 2011

For recycling to achieve its intended purpose of contributing to plastic waste management, the following recommendations might be helpful. Environmental consciousness is certainly of paramount importance. This is where well designed and continued public awareness campaigns and education is useful. People must be educated on the need to protect and preserve the environment.

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