CHAPTER 1

Basics

1.1 Introduction

The start of civilization has seen human race generating waste such as bones and other parts of animals they slaughter for their food or the wood they cut to make their shelters, tools, carts etc. The advancement of civilization has witnessed the waste generation getting enhanced, and becoming more complex in nature. The beginning of industrial era has had enormous effect on the life styles of people which have started changing with the availability of many consumer products and services in the market. The manufacturing and usage of vast range of products as well as management of the resulting waste give rise to emission of greenhouse gases. This has led not only to the pollution of air and water but has affected the Planet Earth through global warming.

Rapid migration of rural populations to urban centres, in search of better opportunities of livelihood, has resulted in an overwhelming demographic growth in many cities worldwide. This situation is more pronounced especially in Asia and Africa. The projected growth rate in North America is less because it has already recorded a growth rate of > 70%. Also in Europe, the situation is similar. But in Africa and Asia, around 35% of the population presently is urban (Fig.1.1). Asian countries are experiencing an urban growth of approximately 4% per year. This growth rate is expected to continue for several more years, and by 2025, 52% of the Asian population is likely to be living in urban centres. As in Asia, Africa's population is mainly rural at present. However, Africa is also experiencing a high rate of urbanization at 4 to 5 % per annum, and by 2025, urbanization is likely to be similar to Asia. This high rate of urbanization can lead to serious environmental degradation in and around several cities.

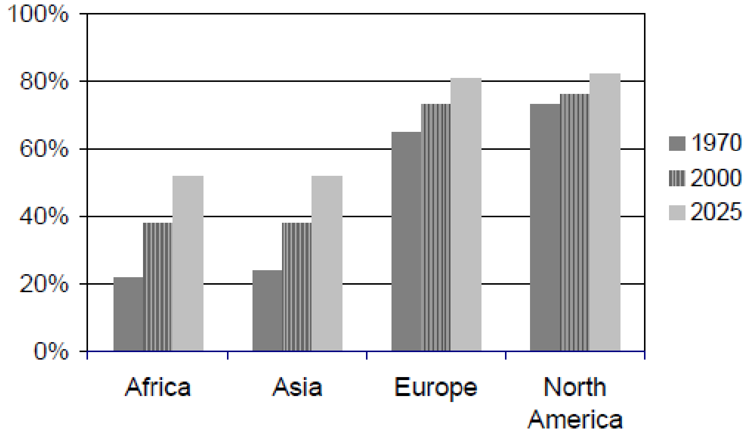

Fig. 1.1 Projected urban growth in different continents (source: UN 1996)

Cities and towns in India, a developing economy, have generated an estimated 6 million tonnes of solid waste in 1947. It has risen to about 48 million tons in 1997; and in 2001, to more than 91 million tons (taking the urban areas only), which comes to 0.12 to 0.6 kilograms per person per day. In contrast, in 2006, a developed country like US has generated more than 251 million tons of municipal solid waste which amounts to approximately 2.1 kilograms of waste/ person/ day. This is in addition to approximately 7.6 billion tons of industrial solid waste generated by industrial units annually. On an average, per capita waste generation in US (a developed country) is very *much higher* than in India (a developing country).

Significance of Waste management: Waste is any garbage or refuse or other discarded material including solid, liquid, semi-solid, or contained gaseous material arising from domestic, community, industrial, commercial, agricultural or human operations. The sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility is also considered as waste.

Waste management is a global issue and requires maximum attention. It is highly obligatory to reduce the pollution of air and water, the dreadful effects on human health and to maintain a clean environment. Waste management sector can contribute to greenhouse gas mitigation in ways that are economically viable and meet many social priorities. The adverse effects of global warming are witnessed already around the globe to varying degree in different regions. A safe and sustainable environment is an absolute necessity for a healthy living. The civic society has, therefore, exclusive responsibility of considering waste treatment as a priority issue.

The management of waste involves waste collection, resource recovery and recycling, transportation, and processing or disposal. Of these, the most important one is processing/disposal of waste. The urbanized areas are concerned with the problem of developing cost-effective environmentally acceptable disposal methods of solid waste. The major advantages of a planned approach to waste treatment are (i) reducing pollution and the consequences such as global warming, (ii) keeping the human habitats ranging from small towns to big cities clean and green, (iii) recovering 'resources' which can be recycled into useful products for reuse, and more importantly (iv) processing of wastes into useful clean energy – heat and electric power.

Since the waste can be solid, liquid, gaseous or medical or hazardous substances, each category is treated with different and appropriate method(s). Waste management practices differ in developed and developing countries, in urban and rural areas, and for residential and industrial producers. Waste management has to be viewed as a central element in the sustainable development planning of a city or a town or a community.

Management of non-hazardous residential and institutional waste in metropolitan areas is usually the responsibility of local municipal authorities/urban local bodies, while management for hazardous commercial and industrial waste is usually the responsibility of the producer.

1.2 Types of Solid Waste

(Courtesy Photos: CPREEC website)

Domestic wastes are generated by household activities such as cooking, cleaning, repairs, interior decoration, and used products/ materials such as empty glass/ plastic/ metal containers, packaging stuff, clothing, old books, newspapers, old furnishings, etc. *Commercial wastes* are the wastes generated in offices, wholesale stores, shops, restaurants and hotels, vegetable, fish and meat markets, warehouses and other commercial establishments. *Institutional wastes* are generated from institutions such as schools, colleges, hospitals, research institutions. The waste includes mostly paper, cardboard, etc., and hazardous wastes. *Municipal wastes* are wastes generated due to municipal services such as street sweeping, and dead animals, market waste and abandoned vehicles or parts; also includes already mentioned domestic wastes, institutional wastes and commercial wastes.

Garbage includes animal and vegetable wastes due to various activities like storage, preparation and sale, cooking and serving; these are biodegradable.

***Ashes*:** Residues from the burning of wood, charcoal and coke for cooking and heating in houses, institutions and small industries. Ashes consist of fine powders, cinders and clinker often mixed with small pieces of metal and glass.

***Rubbish*:** Apart from garbage and ashes, other solid wastes produced in households, commercial establishments, and institutions.

***Bulky wastes*:** Bulky wastes are large household appliances such as cookers, refrigerators and washing machines as well as furniture, crates, vehicle parts, tyres, wood, trees and branches. The bulky metallic wastes are sold as scrap metal but some portion is disposed as sanitary landfills.

Street wastes: Street wastes include paper, cardboard, plastic, dirt, dust, leaves and other vegetable matter collected from streets, walkways, alleys, parks and vacant plots. Municipal waste includes street waste also.

Dead animals: It includes animals that die naturally or killed by accident. It does not include carcass and animal parts from slaughterhouses as these are considered as industrial wastes.

Construction and demolition wastes: Some quantities of the major components of the construction materials such as cement, bricks, cement plaster, steel, rubble, stone, timber, plastic and iron pipes are left out as waste during construction as well as demolition. About 50% of the wastes are not currently recycled in India and 70% of the construction industry in India is not aware of recycling techniques.

Industrial wastes: These are non-hazardous solid material discarded from manufacturing processes and industrial operations, and are not considered as municipal wastes. However, solid wastes from small industrial plants and ash from power plants are frequently disposed of at municipal landfills.

Table 1.1 Source and quantum of some major industrial wastes in India.

Sl No.	Waste	Quantity (Million tonnes per annum)	Source
1	Steel and Blast Furnace	35.0	Conversion of steel
2	Brine mud	0.02	Caustic soda industry
3	Copper slag	0.0164	By product from smelting of copper
4	Fly ash	70.0	Coal based thermal power plants
5	Kiln dust	1.6	Cement plants
6	Lime sludge	3.0	Sugar, paper, fertilizer, tanneries, soda ash, calcium carbide industries
7	Mica scraper waste	0.005	Mica mining areas
8	Phosphogypsum	4.5	Phosphoric acid plant, Ammonium phosphate
9	Red mud / Bauxite	3.0	Mining and extraction of alumina from Bauxite
10	Coal washery dust	3.0	Coal mines
11	Iron tailing	11.25	Iron Ore
12	Lime stone wastes	50.0	Lime stone quarry

(Source: Manual on Municipal Solid Waste Management, CPHEEO, New Delhi)

Major producers of industrial wastes are the thermal power plants producing coal ash; integrated iron and steel mills producing blast furnace slag and steel melting slag; non-ferrous industries like aluminium, zinc and copper producing red mud and tailings; sugar industries generating press mud; pulp and paper industries producing lime, and fertilizer and allied industries producing gypsum. It is mandatory for the industries that generate wastes to manage by themselves. It is also mandatory to obtain prior permission from the respective state pollution control boards to start such industries under relevant rules. The industrial wastes, and the sources with quantities generated in India are given in Table 1.1.

***Slaughter House Waste*:** India has the world's largest livestock population. According to the Ministry of Food Processing, Government of India, a total of 3616 slaughter houses exist. They slaughter over 2 million cattle and buffaloes, 50 million sheep and goat, 1.5 million pigs and 150 million poultry annually, for domestic as well as export purposes. Slaughtering of animals generates both liquid and solid wastes consisting of non-edible organs, stomach contents, dung, bones and sludge from waste water treatment. The large type of slaughter house generates 6-7 tonnes; the medium type generates 2-6 tonnes; and small type generates 0.5-1.0 t/day. Central Pollution Control Board in India has brought out "Draft guidelines for sanitation in slaughter houses" in 1998.

In broader sense of the term, the *Municipal solid waste* (MSW) covers decomposable wastes such as food and vegetable wastes (cooking waste), and non decomposable wastes such as *metals* (aluminum, steel, etc.), *glass* (clear, colored, etc.), *paper* (newsprint, cardboard, etc.), *natural polymers* (leather, grass, leaves, cotton, etc.), and *synthetic polymers* (synthetic rubbers, polyethylene terephthalate, polyvinyl chloride etc.), Similarly, the *Industrial waste* is made up of a wide variety of non-hazardous materials that result from the production of goods and products. Commercial and institutional, or industrial waste is often a significant portion of municipal solid waste, even in small cities and suburbs.

Some of the wastes referred to as *Special wastes* include (i) Cement kiln dust, (ii) Mining waste, (iii) Oil and gas drilling muds and oil production brines, (iv) Phosphate rock mining, beneficiation, and processing waste, (v) Uranium waste, and (vi) Utility waste (i.e., fossil fuel combustion waste). These are generated in large volumes and are believed to cause less risk to human health and the environment than the wastes specified as hazardous waste.

***Medical Waste* (or Hospital waste):** It refers to the waste materials generated at health care facilities, such as hospitals, clinics, physician's offices, dental practices, blood banks, and veterinary hospitals/clinics, as well as medical research facilities and laboratories. The Medical waste is defined as "any solid waste that is generated in the diagnosis, treatment, or immunization of human beings or animals, in related research, or in the production or testing of biological." For example, the following trash constitutes medical waste: blood-soaked bandages, culture dishes and other glassware, discarded surgical gloves, discarded surgical instruments, discarded needles used to give shots or draw blood, cultures, stocks, swabs used to inoculate cultures, removed body organs (e.g., tonsils, appendices, limbs), and discarded lancets. Several health hazards are associated with poor management of medical wastes like injury from sharps to staff and waste handlers associated with the health care establishments, Hospital Acquired Infection (HAI) of patients due to spread of infection, and Occupational risk associated with hazardous chemicals, drugs, unauthorized repackaging and sale of disposable items and unused/date expired drugs. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific manner. It has been roughly estimated that of the 4 kg of waste generated in a hospital at least 1 kg would be infected.

***Hazardous waste*:** The waste that is dangerous or potentially harmful to human health or the environment is called hazardous waste which can be in the form of liquids, solids, gases, or sludge. The discarded commercial products like cleaning fluids or pesticides, or the by-products of manufacturing processes can also be hazardous.

Degeneration times for wastes: The approximate times that different types of garbage take to degenerate are (source: Prakriti, Dibrugarh Univ.):

Organic waste, i.e., vegetable and fruit peels, leftover foods etc: A week or two,

Paper: 10–30 days,

Cotton cloth: 2–5 months,

Wood: 10–15 years,

Woolen items: 1 year,

Tin, aluminium, and other metal items(such as cans): 100–500 years,

Plastic bags: One million years?

Glass bottles: Undetermined

E-waste: Electronic waste or e-waste is referred to the end-of-life electronic and telecommunication equipment and consumer electronics; to be specific, computers, laptops, television sets, DVD players, mobile phones etc., which are to be disposed. UN estimates that between 20 and 50 million tons of e-waste is generated world-wide every year and approximately 12 million tons of this comes from Asian countries. (source: Electronic Waste Recovery Business).

Although much of the e-waste comes from developed countries, considerable quantities also originate from within India. As of March 2009, approximately 400,000 tons of e-waste was produced in India; 19,000 tons of this came from Mumbai, the largest e-waste generator in the country (source: Toxics Link).

E-waste is the fastest growing segment of the MSW stream. E-waste equals 1% of solid waste on average in developed countries which grew to 2% by 2010. In developing countries, like India, E-waste forms 0.01% to 1% of the total solid waste. Globally, computer sales continue to grow at > 10% rates annually. Sales of DVD players are doubling year over year. Yet the lifecycle of these products are shortening, shrinking to 10 years for a television set to 2 or 3 years for a computer. As a result, a high percentage of electronics are ending up in the waste stream releasing dangerous toxins into the environment. These are a division of WEEE (Waste Electrical and Electronic Equipment). The categories under WEEE are: large household appliances, small household appliances, IT and telecommunication equipment, consumer equipment, lighting equipment, electrical and electronic tools, medical devices, monitoring and control instruments and so on. Most of the equipment is made of components, some of which contain toxic substances. If proper processing and disposal methods are not followed, these substances affect human health as well as the environment. For example, cathode ray tubes contain large amounts of carcinogens such as lead, barium, phosphor and other heavy metals. If they are broken or disposed in an uncontrolled manner without taking safety precautions, it can result in harmful effects for the workers, and pollute the soil, air and ground water by releasing toxins.

Special care is warranted during recycling and landfilling of e-waste as they are prone to hazards.

1.3 Waste Management Concepts

There are a number of *concepts about waste management* which vary in practice between countries or regions as already mentioned. Some of the most general, widely-used concepts include:

(i) ***Waste hierarchy:*** Waste hierarchy proposes that waste should be managed by different methods according to its characteristics. The preference of the options represents the hierarchal structure. Thus, prevention, reuse and recycling are given the highest preference, while open burning is unacceptable. The hierarchy is designed to improve the environmental aspects of ISWM. Practices, which produce serious impacts on the environment, are the least accepted ones.The waste hierarchy is an accepted key element of ISWM (see Annexure 9 for ISWM). The waste management plans are to derive the most useful benefits from products and to generate the minimum amount of waste, and are listed according to their desirability in terms of *waste minimization*. The Waste hierarchy is schematically represented in Fig.1.2.

(ii) ***Extended producer responsibility:*** PR is a strategy designed to promote the integration of all costs associated with products throughout their life cycle (including the end-of-life disposal costs) into the market price of the product. Extended producer responsibility is meant to impose accountability over the entire lifecycle of products. This means that firms which manufacture and trade in products are required to be responsible for the products not only during manufacture but after their useful life also.

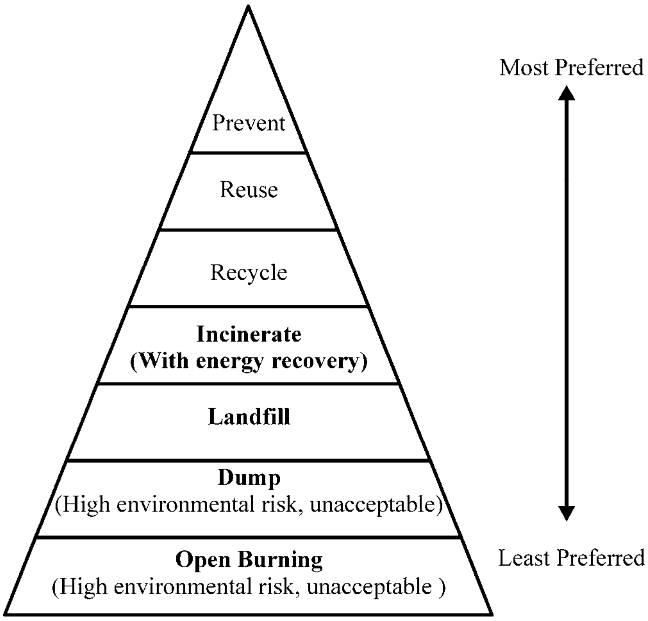

Fig. 1.2 Waste hierarchies.

(iii) Polluter Pays Principle relates to the polluting party paying for the impact caused to the environment. With respect to waste management, a waste generator is required to pay for the disposal of the waste.

1.4 Health and Environmental Impacts

A large number of components in MSW create health and environmental problems. Health impacts include exposure to toxic chemicals through air, water and soil media; exposure to infection and biological contaminants; stress related to odor, noise, pests and visual amenity; risk of fires, explosions, and subsidence; and spills, accidents and transport emissions.

The occupational hazards associated with waste handling according to UNEP Report (1996) are:

Infections: Skin and blood infections resulting from direct contact with waste, and from infected wounds; Eye and respiratory infections resulting from exposure to infected dust, especially during landfill operations; Different diseases that result from the bites of animals feeding on the waste; and Intestinal infections that are transmitted by flies feeding on the waste;

Chronic diseases: Workers at Incineration plants are at risk of chronic respiratory diseases, including cancers resulting from exposure to dust and hazardous compounds;

Accidents: Bone and muscle disorders resulting from the handling of heavy containers; infecting wounds resulting from contact with sharp objects; poisoning and chemical burns resulting from contact with small amounts of hazardous chemical waste mixed with general waste; burns and other injuries resulting from occupational accidents at waste disposal sites or from methane gas explosion at landfill sites. Some common parasites and pathogens connected with solid waste are given in Table 1.2.

Table 1.2 Common parasites and pathogens associated with waste (Ref: CPREEC)

Organisms	Time and Temperature for destruction
S. Typhosa	No growth beyond 46 °C, death in 30 minutes at 55-60° and 20 minutes at 60 °C, destroyed in a short time in compost environment
Salmonella sp.	In 1 hour at 55 °C and in 15-20 minutes at 60 °C.
Shigella sp.	In 1 hour at 55 °C.
E. Coli	In 1 hour at 55 °C. and in 15-20 minutes at 60 °C.
E. histolytica cysts	In few minutes at 45 °C. and in few seconds at 55 °C.
Taenia saginata	In a few minutes at 55 °C.
Trichinella spiralis larvae	Quickly killed at 55 °C, instantly at 60 °C.
Br. Abortus or *Br. Suis*	In 3 minutes at 62-63 °C and in 1 hour at 55 °C.
Micrococcus pyogenes var. aureus	In 10 minutes at 54 °C.
Streptococus pyogenes	In 10 minutes at 54 °C.
Mycobactercum tuberculosis var. hominis	In 15-20 minutes at 66 °C. or after momentary heating at 67 °C.
Corynebacterium diptheriae	In 45 minutes at 55 °C.
Necator americanus	In 50 minutes at 45 °C.
A. lumbricoides eggs	In 1 hour at 50 °C.

The environmental impacts can be pollution and global warming, photochemical oxidant creation, abiotic resource depletion, acidification, eutrophication, and eco toxicity to water. The communities, industries, and individuals have, therefore, found several ways to reduce and better manage Municipal Solid Waste through a combination of practices not only to extract reusable components but to generate energy in the form of heat or electricity. These practices include source reduction, recycling, and processing/disposal through different technologies such as composting, combustion/incineration, gasification, anaerobic digestion, landfill and so on.

There are several factors that influence successful management of the solid waste, and the vital ones are: Awareness creation among people about the benefits of proper waste disposal, emphasis on waste reduction, long range self sustainability as well as technical feasibility, institutional arrangements, for example, ensuring market for the products, involving community as well as other stakeholders in the waste management programme.

Several Waste processing/treatment and disposal technologies are available for environmentally sound management of MSW. These are broadly grouped as:

Established waste treatment technologies, such as Recycling, Composting, Landfill, Incineration, and Windrow composting; and *Alternative waste treatment* technologies such as Gasification, Pyrolysis, In-vessel composting, Anaerobic digestion, Mechanical biological treatment, Mechanical heat treatment, Sewage treatment, Tunnel composting and Waste autoclave. These technologies enable us to derive clean energy (heat and/or electricity) and resources recovery from the waste before its proper disposal.

Before discussing these technologies, let us look at how a successful waste management system would help to combat global warming. Global warming is a subject of local, regional, national and international concern, because of its severe impacts on the humans and the environment in several ways. These impacts are currently witnessed, and are projected to affect the future generations as well.

1.5 Global Warming

Majority of climate experts feels that Global warming has been the most significant environmental issue that mankind has ever faced. It is an issue with implications for the future generations too. Over the last few decades, thousands of scientists worldwide have engaged in intensive research to understand the reasons and the reality of global warming, and its near- and long-term impacts on the people and the planet Earth. The scientific studies have led to the conclusion that the global warming is ‘real’ and is ‘happening’. The 2007 Report of the Intergovernmental Panel on Climate Change (IPCC) has established that the warming is ‘unequivocal’, and the increase in global average temperatures is a result of pollution caused by human activities such as fossil fuels usage, agricultural operations, land-use change and deforestation.

What is global warming? The presence of greenhouse gases in the atmosphere from ‘natural’ and ‘human-made’ sources is essential because they trap heat and keep the planet Earth warm enough for the life to survive. This effect known as ‘natural’ greenhouse effect sustains life that includes humans, animals, insects, birds, all ecosystems etc., on the planet. It has been observed, however, that there have been significant fluctuations in the concentrations of greenhouse gases in the atmosphere over the millennium. Their concentrations have been on the rise since the start of Industrial revolution in the 1700s; and during the most recent two decades, their increase particularly that of carbon dioxide, methane and NO_x have been significant. This has been happening due to the growth of cement, paper, steel and other industrial units, power generation plants, cars, trucks and other vehicles, as well as agricultural activities. In addition, indiscrininate destruction of forests and trees has aggravated the problem. Consequently, the greenhouse effect is ‘enhanced’ and average surface temperature of Earth and oceans have recorded an increase. This is referred to as ‘global warming’. Industrialised countries, particularly USA, account for most of the increase of these heat trapping gases. Fast developing countries like China and India, consequent to their increased development activities over the last few years to eradicate poverty and to improve the GDP have joined the group of top emitters of greenhouse gases. Due to the enhanced concentrations of these gases or ‘enhanced greenhouse effect’, the global average temperatures have risen by 1.3±0.32°F during 1906-2005, most of it occurring since 1975. The rise in temperatures is continuing at an accelerating pace, with 2008 as the 10^{th} warmest year on record. The global warming is starkly evident not only in the rise of global average temperature, but also in global sea level rise, melting of glaciers and thinning of snow cover in the Arctic, Antarctic and other regions, and permafrost thawing, to mention a few.

The *impacts* of the global warming on the global climate and the environment have been extensive and varied (2007 IPCC Reports, Jayarama Reddy 2011). We are witnessing extreme hot days and cold nights, heat waves and wild fires, more frequent and severe storms, cyclones, and droughts, change in precipitation patterns, spread of disease to regions previously unknown, migration of birds and plants to cooler regions, extinction of certain plant and animal species etc., in different regions of the world. There have been many more early signals observed as a result of global warming in all the continents during the last two to three decades. The frequency and severity of these impacts have been differing over the regions of the globe.

The simulations of the specially developed *climate models* indicate a continual warming of the planet if the current rates of greenhouse gas emissions continue, with the temperatures rising by another 2.7 to 11°F by 2100. This huge rise could trigger a wide range of changes in the global climate in this century and beyond. The projected climate changes may occur at an enhanced rate compared to what we have been experiencing, and affect adversely the ecosystems, agriculture and food supplies, water resources, coastal regions, human health and settlements, and in general, the entire environment. The island-states and countries like Bangledesh are threatened by sea level rise. The observations over the recent decades point out that many aspects of climate change are happening *faster* and *with more severity* than what climate models have projected.

Both developed and developing countries have recognised that the increase of greenhouse gases in the atmosphere and the resulting climate change weaken the economies, disrupt the development of the countries, especially poorer countries which are more vulnerable to climate change, and adversely affect people and the environment. As early as in 1980s, very many countries met for the first time and approved an agreement called Montreal Protocol, to control CFCs which impact the protective ozone layer. The Earth Summit held in Rio de Janeiro in 1992 with the participation of over 180 countries was a mega event where a full range of environmental issues were addressed; and an international treaty, 'United Nations Framework Convention on Climate Change (UNFCCC)' was formulated to set a goal of 'stabilising' greenhouse gas concentrations in the atmosphere at safe levels. Under the Framework Convention, an agreement called 'Kyoto Protocol' that set targets for the industrialized countries (called Annex-1 countries) to curb their greenhouse gas emissions to an average of 5.2% below their 1990 emission levels came into force in 2005, and began to bind for ratified countries in 2008. More than 180 countries ratified the Protocol, which might be considered as the the first multinational step to limit greenhouse gas emissions. The largest emitter country, US and Australia, though signatories, did not ratify. The Kyoto Protocol (KP) will expire by 2012, and some of the countries that accepted the targets are unlikely to fulfill for two reasons: (i) KP may not provide adequate conformity incentives, and (ii) The most developed and the largest polluting country, US, is not bound by KP since it has not ratified.

Three market-oriented mechanisms, Clean Development Mechanism, Joint implementation, and Emissions Trading, were formulated to help the Annex-1 countries to reduce the costs of meeting their obligations under Protocol. The Clean development Mechanism (CDM) is a project-based mechanism where industrialized countries can purchase carbon benefits from projects implemented in developing countries to meet their emission reduction obligations. In the developing countries, these project investments help to promote projects attuned to sustainable development such as clean energy projects (examples: solar, wind, biomass, waste-to-energy, clean coal technology etc). The CDM enjoys solid support in developing countries; a large number of projects are undertaken in these countries in the areas of renewable energy generation and solid waste management. In US, despite non-ratification of the Protocol by the federal government, many States and several major industries have voluntarily designed policies and programmes to reduce greenhouse gas emissions. The European Union has unilaterally committed to higher targets of emission reductions than those specified in the Protocol and has come up with new green processes and technologies. Despite these efforts, the global greenhouse gas emissions have been steadily increasing.

Today, US and China each contribute 20% of world's greenhouse gas pollution, European Union 14%, Russia and India 5% each. The fast developing economies, China, India, Brazil and Russia currently figure among the major emitters of greenhouse gases as well as in the world's top ten consumers of energy due to the wide spectrum of their economic activities. If the trend continues, especially in China and India, their emission levels may exceed those of many developed countries. Yet they are not inclined to agree to time-bound targets for emission reductions citing their relatively low 'emissions per head' compared to those of developed countries. The per capita CO_2 emission for different countries, in metric tons, are: USA: 20.01, EU: 9.40, Japan: 9.87, Russia: 11.71, China: 3.60, India: 1.02, and World Average: 4.25 (taken from India's National Action Plan 2008). With large populations and with no sign of reverse in the population growth, the 'per head emissions' are likely to remain low for many more decades for China and India. They are, however, committed to be a part of international initiative in tackling climate change, as reflected in their energy, environmental and climate policies and actions. The eradication of poverty and human suffering take priority over the issues of global climate in the developmental plans of these countries.

Adaptation to the climate change by humans and systems is a way to reduce the cost and severity of impacts currently as well as in the future. So, the adaptive measures to climate change were initiated at local, regional, national and global levels in vital sectors like water resources, energy, agriculture, coastal communities, buildings, and human health. Mitigation actions to reduce greenhouse gas emissions help to stabilize or reverse their concentrations in the atmosphere. The mitigation plans are extensive and mostly sector-dependent; and differ in developed and developing countries because of dissimilar socio-economic conditions and other factors such as technology and infrastructure availability and public awareness. Both the adaptation and mitigation actions are essential; they are a combined set of actions in an overall strategy to reduce greenhouse gas emissions as well as to prepare the humanity to confront the impacts of climate change.

The global population is projected to reach 7.8 to 10.9 billion by 2050. This growth demands more energy, food, housing, goods and services, transport, so on. Burning of more fossil fuels to meet the energy needs, clearing of forests to provide for settlements, and growth in urbanization will not only affect economic and social development but also the environmental sustainability. To contain this trend, services such as family planning, and related health care and education must be extensively provided, especially in the developing countries. If the global population is not controlled, stabilisation of global warming may not be successfully manageable. Deployment of available low-carbon and energy-efficient technologies for manufacturing goods, increase of clean, renewable and advanced nuclear energy sources in the energy mix to reduce dependence on fossil fuels, and energy efficiency practices need to be undertaken on a greater scale.

The costs of implementing the new clean-coal technologies are currently high. While many developed countries have the means to implement clean energy sources and improve energy efficiency, the developing economies can hardly undertake, especially as a short term approach. These countries look for serious funding for adoption of these new technologies. CDM can be one source of funding; but it has to be remodeled by removing bottle-necks with the experience gained so far and implemented in the developing countries on a bigger scale.

The energy-intensive life-styles and behavioural trends of people in the rich countries and of affluent or high-income people in other countries enhance the carbon footprints. The people therefore have to get accustomed to low-energy and low resource consumption practices. Changes that stress on resource and energy conservation may hardly be achievable over shorter time scale, but can certainly lead to slow down greenhouse gas emissions, and to low-carbon economy. Global collaboration and cooperation among the countries which significantly emit greenhouse gases can ensure a sustainable environment and global security. The present generation has the obligation to help preserve the global environment and to promote health, education, and economic opportunity for everyone on the planet and for the generations that follow. Therefore, much needs to be done globally by the governments, organizations, and people to meet the challenges of global warming.

Waste management is perhaps a low-cost mitigation option to reduce emissions and promote sustainable development. For instance, Landfills are a major source of greenhouse gases (particularly methane, which warms the atmosphere more quickly than carbon dioxide), and also contaminate groundwater. Incinerators and other burning and thermal treatment technologies such as biomass burners, gasification, pyrolysis, plasma arc, cement kilns and power plants using waste as fuel, are a direct and indirect source of greenhouse gases to the atmosphere and convert resources that should be reduced or recovered into toxic ashes that need to be disposed of safely. Hence, all technologies available for treating waste to avoid emissions, such as Recovery of methane from landfills, Waste incineration with energy (electric power) recovery, Composting of organic waste, Biomethanation to produce biogas, Controlled waste water treatment for reuse of water, and Recycling and waste minimization need to be effectively deployed. Development of *Bio covers and bio filters to optimize* CH_4 *oxidation* would further help to reduce methane concentrations in the atmosphere.

These are not difficult to deploy; Governments must extend financial and institutional incentives for improved waste and waste water management, which may stimulate technology development and diffusion as co-benefits. The environment policies must include regulations regarding waste collection and disposal, enforcement strategies, and effective implementation at national level. The MSW Rules 2000, other Acts and legal provisions announced by Government of India in the last one decade are good enough to meet most of these aspects. More stringent rules and regulations are in place in the developed/ industrialized countries compared to developing countries. Most of the poorer countries are yet to develop scientific systems for waste management that include resource recovery and energy generation.

Waste related mitigation options have tremendous co-benefits in terms of improved *public health and safety, pollution prevention, soil protection and clean energy supply.*

1.6 Source Reduction

Chapter 21 of Agenda 21, a document adopted by the United Nations as a blueprint on action for environmental protection up to the twenty first century, unequivocally states that environmentally sound waste management must go beyond the mere safe disposal and recovery of waste that is generated (UNCED, 1992). Instead, it must seek to address the root cause of the problem by attempting to change unsustainable patterns of production and consumption. The problem of tackling waste starts with waste reduction at the manufacturing stage itself by going for innovative technologies and newer materials.

We use many materials and products in our day-to-day activities. These have specific lifetimes after which they become useless and we throw them as trash. Part of the trash can be recycled and reused, and the rest be disposed. The ‘disposed’ portion can be minimized or prevented at the stage of product manufacturing or its usage. The change in the design or manufacturing process or use of products and materials to reduce the waste prevention is known as "source reduction". Source reduction is the practice of designing, manufacturing, purchasing, or using materials or products and packaging in such ways that reduce the amount as well as the toxicity of the trash created.

Waste generation could be reduced if the local and national stakeholders (environmental and civic bodies) follow the concept of ‘product stewardship’. This concept would persuade manufacturers to gear up towards environmental concepts of resource utilization with focus on costs and benefit of product development, consumption, disposal and resource recycle. Product stewardship follows the ‘cleaner production (CP)’ approach whereby waste generation at the upstream is targeted for reduction rather than abating downstream. Since all parties responsible during the life cycle of a product are involved, they have a role to play in managing the waste generated. The MSWM framework cannot achieve the adoption of this concept alone but has to coordinate it closely with the waste generators, manufacturers and the product middlemen until the consumer’s end.

What is Product stewardship? It can be defined as a product life cycle where all parties responsible for the design, production, sale and use of a product assume responsibility for its environmental impacts throughout its life cycle. The concept of product stewardship incorporates the following principles:

1. All parties who have a role in designing, producing, selling or using a product or product components should assume responsibility for (a) reducing or eliminating toxic and/or hazardous constituents in products and/or its components, (b) reducing the toxicity and amount of waste that results from manufacture, use and disposal of the products; and (c) developing products that use materials, energy and water efficiently at every stage of a product's life cycle including manufacture, distribution, sale, use and recovery.
2. The greater the ability of a party to influence life-cycle impacts of the product, the greater the degree of responsibility the party should have to minimize them.
3. Those responsible for the design, production, sale or use of a product should have flexibility to determine how to reduce toxic and/or hazardous constituents in it and how to keep materials from becoming waste.
4. The costs of recovering resources and managing products at the end of their useful life should be internalized into the costs of producing and selling them.
5. Government should provide leadership in the area of product stewardship in all its activities, including, but not limited to, promoting it when it purchases products, making capital investments in green buildings and infrastructure, procuring services, and managing them at the end of their useful life (EPA 2003 at (http://www.epa.gov/epr/index.htm).

Green dot system: Many developed countries and some selected industries (heavy machinery, electronic and beverages to cite a few) in the developing countries have a buy-back system for recyclables which can effectively reduce the volume of waste generated at the consumer's end. Germany has implemented the 'green dot system' which makes it mandatory for the recycling industries to process the collected recyclables. Germany issued an ordinance on packaging in 1991 in an attempt to minimize the quantity of solid waste. The manufacturers are required to take back the packaging of their goods and reuse or recycle it.

The green dot system facilitated the industries to comply with waste management regulations, and its goals were set for collecting the waste and separating it. These two goals aimed to recycle 72 percent of glass, tinplate and aluminum packaging waste, and 64 percent of paper, plastic and composite packaging in Germany. The US, however, reported recycle rate of only 22 percent of glass and tinplate packaging in 1990. The regulations to achieve this ambitious goal would create incentives for the industries to minimize waste during manufacture and packaging. The green dot system concentrates on three types of packaging: transport packaging such as pallets and crates; secondary packaging in containers like boxes for commodities; and primary packaging - actual casing of the product. Companies/manufacturers were unable to meet the recycling quotas on their own and the Dual System was created for them with a membership. Members in the system put the ‘green dot’ trademark on their packaging that guaranteed recycling for their packaging if collected. Drop off and curbside collection for all packaging with the green dot trademark is also available. These recycling receptacles make it more convenient for households to recycle, helping the companies with greater chances to meet the required recycling quotas. As of September 1993, 12000 companies had signed for the green dot programme including 1900 firms based outside Germany.

The green dot system had proved that it could reduce the quantity of waste. In 1992-1993, the consumption of packaging has decreased by about 4%. Containers have been reused and the quantity of secondary packaging has dropped by 80%. The green dot system was responsible for the collection of 4.6 million tons of recyclables in 1993. But, there are some concerns with the system such as the oversupply of recyclable waste, and the necessity for creation of more markets for products made of recyclables. The success of the programme depends on whether the collected waste is fully reused/ recycled or not.

Source reduction is also applicable to domestic, commercial, and institutional sources of waste generation. Source reduction also refers to the ‘reuse’ of products or materials. Reuse can help to reduce waste collection, waste disposal and handling costs, because it avoids the costs of recycling or municipal composting or landfilling or combustion or such other processing methods. Source reduction also helps to conserve resources and reduces pollution. It helps to control emission of greenhouse gases that contribute to global warming, and toxicity of the material that is created.

The source reduction offers several benefits:

(a) ***Saves natural resources:*** Waste is not just created when items are thrown away after use. Throughout the life cycle of a product, from extraction of raw materials to transportation to processing and manufacturing and use, waste is generated. By reusing the items or by making those with less material, the waste will substantially decrease. Ultimately, fewer materials will need to be recycled or sent to landfills or waste combustion facilities.

(b) ***Reduces toxicity of waste:*** Selecting nonhazardous or less hazardous items is another important component of source reduction. Using less hazardous alternatives for certain items (e.g., cleaning products and pesticides), sharing products that contain hazardous chemicals instead of throwing out leftovers, reading label directions carefully, and using the smallest amount necessary are ways to reduce waste toxicity.

(c) ***Reduces costs:*** Apart from reducing dependence on methods of waste disposal, preventing waste also can mean economic savings for communities, businesses, institutions, and individual consumers.

(d) ***Benefits Industry:*** Industry also has an economic incentive to practice source reduction. When businesses manufacture their products with less packaging, they are buying fewer raw materials. A decrease in manufacturing costs can result in a larger profit margin, with savings that can be passed on to the consumer.

(e) ***Benefits Consumers:*** Consumers can share the economic benefits of source reduction. For instance, if products are bought in bulk or with less packaging or that are frequently reusable, then there will be cost savings. It means what is good for the environment can as well be good economically.

For example, look at the Source Reduction and Reuse facts in USA in 2000: More than 55 million tons of MSW were source reduced. Containers and packaging represented approximately 28 percent of the materials source reduced, in addition to nondurable goods (e.g., newspapers, clothing) at 17 percent, durable goods (e.g., appliances, furniture, tires) at 10 percent, and other MSW (e.g., yard trimmings, food scraps) at 45 percent. There are more than 6,000 reuse centers around the country, ranging from specialized programmes for building materials or unneeded materials in schools to local programmes such as Goodwill and the Salvation Army, according to the Reuse Development Organization.

Between two and five percent of the waste stream is potentially reusable according to local studies in Berkeley, California and Leverett, Massachusetts. Between 1960 and 2008, the amount of waste each person creates in USA has almost doubled from 2.7 to 4.5 pounds per day. The most effective way to stop this trend is by preventing waste in the first place. Since 1977, the weight of 2-liter plastic soft drink bottles has been reduced from 68 grams each to 51 grams. That means that 250 million pounds of plastic per year has been avoided in the waste stream.