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[Report and Opinion]

Scenario of solid waste management in present Indian context

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ABSTRACT
A trend of significant increase in municipal solid waste generation has been recorded worldwide. This has been found due to over population growth rate, industrialization, urbanization and economic growth. Consumerism speed has been found very high covering around more then 50% of total population since last decade due to higher economic growth, which has ultimately resulted in increased solid waste generation. Municipal solid waste generation showed different trend and a positive correlation with economic development in term of kg/capita/day solid waste generation at world scale. Municipal solid waste generation has been recorded much higher in western and some eastern developed countries. Solid waste generation kg/capita/day was found 2 kg in USA, 1.89 kg in Australia, 1.8 kg in Canada, 1.83 kg in Ireland, 1.1 kg in Belgium and Switzerland, 0.99 kg in Spain, 0.96 kg in Italy, 0.85 kg in Mexico and Greece during 1992 as per report and expected to be increased at least 25% by 2005 due to population and economic revolution. Similarly solid waste generation in several developing countries and cities has been found in South East Asia region. Some important data can be mentioned such as 1.2 kg in Changging (1997), 0.6 kg in Shanghai (1993), 0.88 kg in Beijing (1991), 1.17 kg in Hong Kong residential cities and 3.9 kg commercial (1994), 1.5 kg in Tokyo, 2.7 kg in Osaka, Japan (1993), 0.66 kg in Jakarta, Indonesia (1993), 1.29 kg in Kuala Lumpur, Malaysia (1989), 0.53 kg in Metro Manila Philippines (1995), 0.5 kg in Khulana, Dhaka, Chittagong, 0.4 kg Sylhat, Bangladesh (1991). Total Solid waste generated in Tons/day would be proportionate to the population of specific city in that specific/mentioned year. Population growth and solid waste generation in India has varying trend and correlation between population and solid waste generation of specificity is not necessary to be applicable. Population growth and solid waste generation in India has varying trend and correlation between population and solid waste generation of specific city is not necessary to be applicable. Population increased from 8.2 to 12.3 million in Mumbai during the period of Ten years (1981-97) at the rate of 49%. Similarly the population growth has been found to rise exponentially in other Indian cities; however, the growth rate may be varying. Trend of urbanization played significant role in enhancement of solid waste generation and in India it was 27.8% in 2001 and expected to reach 41% by 2021. In certain Indian cities, Solid waste generation has been found in 1995 was 0.64 kg in Kanpur, 0.52 kg in Lucknow, 0.4 kg in Varanasi, 0.59 kg in Ahemadabad and 0.44 kg in Mumbai. Currently total solid waste generated in India is around 42 million tons annually. Waste generation varies from 200-600 kg/capita/day and collection efficiency ranges from 50-90%.

Keywords: Incineration, Land filling, Solid Waste, Solid Waste Management.

INTRODUCTION
Solid waste may be defined as generation of undesirable substances which is left after they are used once. They cannot be reused directly by the society for its welfare because some of them may be hazardous for human health. Covering of various vegetables, fruits and cooked material facilitate proliferation of various group of microbial flora, which may be pathogens. Since the beginning, human kind has been generating waste, the bones and other parts of animals they slaughter for

their food or the wood cut to make their carts with the progress of civilization, the waste generated become a more complex nature. By the end of nineteenth century, Industrial development has shown a progressive trend in the world consumers. Presently not only the air but also earth itself becomes more and more polluted specially with generation of non-biodegradable substances (solid waste). Generation of solid waste is a natural phenomenon up to certain extent as all living organism are excreting solid waste after digestion of food material. The amount of solid waste generation is directly proportion to population. Less population means fewer excreta while large population growth will enhance excreta in natural condition. Besides this, utilization of other natural resources for various causes has been considered as human generated solid waste. Since the last five decades due to urbanization, industrialization and change in the habits as well attitude to life has resulted uncontrolled exploitation of different kinds of natural resources and finally generation of large amount of solid waste having more complexity, some of them can not be degraded by micro-organisms and need genetically engineered microbial population for them. Besides this some of them may cause injurious health effect on human beings.

Both biodegradable and non-biodegradable solid wastes are also associated with air pollution in atmosphere in form of inorganic particles and foul odour. Data of solid waste production from domestic and industrial sectors from different countries of the world is very alarming. Therefore under these circumstances it would be more advisable that waste products of one industry should be investigated with objective to use this one as raw material for other industry to get desired product. Albeit it would need more funds for research and development but it would be yield safer economic development.

Since the nature of solid waste generated from different resources has significant variation in the components therefore it is much obvious that their toxicity/hazards ability will be of different level. Industrial and hospital waste generate powerful hazardous toxic substances. These wastes could be highly toxic to man, animal as well as plants. India generates about several million tones of hazardous waste. Hazardous waste generation in India has direct proportion in term of development and progress of the state/cities and showed significant variation among the Indian cities. The solid waste amount is expected to increase significantly in the near future as the country strives to attain an industrializes nation status by the year 2020 (Sharma & Shah, 2005; CPCB, 2004). Total number of units engaged in hazardous waste generation in India are 12584 which are located in different states and some important can be mentioned as in Maharashtra 3953, Gujarat 2984, Tamilnadu 1100 and Uttar Pradesh 1020.

As the result of rapid increase in production and consumption, urban society rejects and generates solid material regularly which leads to considerable increase in the volume of waste generated from several sources such as, domestic wastes, commercial wastes, institutional wastes and industrial wastes. Wastes that arise from a typical urban society comprises of garbage, rubbish (package materials), construction and demolition wastes, leaf litter, hazardous wastes, etc. The type of litter we generate and the approximate time it takes to degenerate is shown in table 1. In India, the amount of waste generated per capita is estimated to increase at a rate of 1% - 1.33% annually (Shekdar, 1999). For example, the population of Mumbai grew from around 8.2 million in 1981 to 12.3 million in 1991, registering a growth of around 49%. On the other hand, municipal solid waste generated in the city increased from 3200 tonnes per day to 5355 tonnes per day in the same period registering a growth of around 67% (CPCB, 2000).

The conditions, issues and problems of urban waste management in the Industrialized and developing worlds are different. Though the developed countries generate larger amounts of wastes, they have developed adequate facilities, competent government institutions and bureaucracies to manage their wastes. Developing countries are still in the transition towards better waste management but they currently have insufficient collection and improper disposal of wastes. Generally, Solid waste is disposed off in low-lying areas without taking any precautions or operational controls. Therefore, Solid waste management is one of the major environmental problems of Indian megacities (Sharholy *et al.,* 2008). Clear government policies and competent bureaucracies for management of solid wastes are needed urgently especially in countries where there is rapid population growth through urbanization into semi-urban areas. Services and programmes that include proper waste disposal for management of hazardous biological and chemical wastes, minimization and recycling will be needed. Disposal of wastes is commonly done by dumping (on land or into water bodies), incineration or long-term storage in a secured facility. All these methods have varying degrees of negative environmental impacts with adverse environmental and health risks if wastes are improperly disposed or stored.

Table 1. Type of litter we generate and approximate time it takes to degenerate.

Type of litter	Approximate time to degenerate
Organic waste (vegetable and fruit peels, foodstuff)	A week or two.
Paper	10-30 days
Cotton cloth	2-5 months
Wood	10-15 years
Woolen items	1 year
Tin, aluminum, and other metal items such as cans	100-500 years
Plastic bags	One million years?
Glass bottles	Undetermined

Source: http://edugreen.teri.res.in

TYPES OF SOLID WASTE AND ITS GENERATION RATE IN DIFFERENT INDIAN CITIES

Solid waste can be classified into following categories:

Domestic waste or Household waste or Municipal waste

The Municipal Solid wastes (Management and Handling) Rules 2000, prescribed under the Environment Protection Act 1986 by the Government of India define municipal waste as "commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes". Municipal solid waste includes the decomposable waste from household products during the preparation of meat, food, vegetable, and waste generated from shops, hotels, offices and other commercial units. With rising urbanization and change in lifestyle and food habits, the amount of municipal solid waste has been increasing rapidly and its composition changing. The characteristics of municipal solid waste collected from any area depend on a number of factors such as food habits, cultural traditions of inhabitants, life styles, climate etc. Total quantity of solid waste generated in urban areas of the country is about 1.15 lakh tones per day. Out of this 19643 tonnes of waste is generated in metro cities per day. The survey conducted by CPCB puts total municipal waste generation from Class I and Class II cities to around 18 million tonnes in 1997 (CPCB, 2000a). The solid waste generated in Indian cities has increased from 6 million tonnes in 1947 to 48 million tonnes in 1997 and is expected to increase to 300 million tonnes per annum by 2047 (CPCB, 2000a). More than 25% of the municipal solid waste is not collected at all, 70% of the Indian cities lack adequate capacity to transport it and there are no sanitary landfills to dispose of the waste. The existing landfills are neither well equipped nor well managed. Also, they are failed to protect against contamination of soil and groundwater.

Biomedical waste or Hospital waste

Hospital waste includes pathological, anatomical, infectious and hazardous wastes, which are produced from health care facilities and medical labs. It is generated during the diagnosis, treatment or immunization of human beings or animals and in research activities in these fields. It may include wastes like anatomical waste, cultures, discarded medicines, chemical wastes, disposable syringes, glucose bottles, cotton swabs, bandages, body fluids, human excreta etc. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific manner. The quantum of waste that is generated in India is estimated to be 1-2 kg per bed per day in a hospital and 600 gm per day per bed in a general practioner's clinic. E.g. a 100-bedded hospital will generate 100-200 kg of hospital waste per day. It is estimated that only 5-10% of this comprises of hazardous or infectious waste (5-10 kg/day). It has been roughly estimated that out of the 4 kg of waste generated in a hospital at least 1 kg would be infected. Surveys carried out by various agencies show that the health care establishments in India are not giving proper attention to their waste management. The Government of India has promulgated the Bio-medical Waste (Handling and Management) Rules, 1998. They are applicable to all persons who generate, collect, receive, store, transport, treat, dispose or handle biomedical wastes. These include hospitals, nursing homes, clinics, dispensaries, veterinary institutions, animal houses, pathological laboratories and blood banks. After the notification of the Bio-medical Waste (Handling and Management) Rules, 1998. They are applicable to all persons who generate, collect, receive, store, transport, treat, dispose or handle biomedical wastes. These include hospitals, nursing homes, clinics, dispelnsaries, veterinary institutions, animal houses, pathological laboratories and blood banks. After the notification of the Bio-medical Waste (Handling and Management) Rules, 1998, these establishments are slowly streamlining the process of waste segregation, collection, treatment, and disposal. Many of the larger hospitals have either installed the treatment facilities or are in the process of doing so.

Hazardous wastes or Industrial waste

Industrial operations lead to considerable generation of hazardous waste and in a rapidly industrializing country such as India the contribution to hazardous waste from industries is largest. Sources of hazardous waste include those from industrial processes, mining extraction; from pesticide based agricultural practices etc. they are corrosive, highly inflammable and explosive. Household wastes that can be categorized as hazardous waste include old batteries, shoe polish, paint tins, old medicines and medicine bottles. Hospital waste contaminated by chemicals used in hospitals is considered as hazardous. These chemicals include formaldehyde and phenols, which are used as disinfectants and mercury which is used in thermometers or equipment that measure blood pressure. Direct exposure to chemicals in hazardous waste such as mercury and cyanide can be fatal. India generates around 7 million tonnes of hazardous wastes every year. States such as Gujarat, Maharashtra, Tamil Nadu and Andhra Pradesh, which are relatively more industrialized face problems of toxic and hazardous waste disposal far more acutely than less developed states. The major hazardous waste generating industries in India include petrochemicals, pharmaceuticals, pesticides, paint and dye, petroleum, fertilizers, asbestos, caustic soda, inorganic chemicals and general engineering industryies. As per the information provided by the Ministry of Environment and Forest (MoEF), there are 323 hazardous waste recycling units in India and of these 303 recycling units use indigenous raw material while 20 depend on imported recyclable wastes. The major types of hazardous waste imported by the country include battery scrap, lead, zinc, ash and galvanized zinc. Industrial waste is considered hazardous as they may contain toxic substances. Hazardous wastes could be highly toxic to humans, animals and plants. They are corrosive, highly inflammable, and explosive and react when exposed to certain things e.g. gases.

Agricultural waste

Agricultural waste is composed of organic wastes (animal excreta in the form of slurries and farmyard manures, spent mushroom compost, soiled water and silage effluent) and waste such as plastic, scrap machinery, fencing, pesticides, waste oils and veterinary medicines. There are a number of potential environmental impacts associated with agricultural waste if it is not properly managed, run-off of nutrients to surface waters which can cause over enrichment of the water body. Leaking and improper storage of agricultural waste can also pose serious threat surface waters. In addition, farming activities can give rise to emissions of ammonia and methane, which can cause acidification and contribute to greenhouse gases emissions.

Radioactive waste

These mainly arises from nuclear power plants, nuclear testing labs, industrial establishment etc. According to the Worldwatch Institute, there are more than 80,000 tons of irradiated fuel and hundreds of thousands of tons of other radioactive waste accumulated so far from the commercial generation of electricity from nuclear power. Irradiated fuel can take hundreds of thousands of years to decay into a harmless substance. Until then, it is extremely dangerous and must be kept far away from possible human contact.

HEALTH IMPACTS

Improper handling of solid waste is a health hazard and may cause severe damage to the environment. At presently most of the Municipal solid waste in the country is disposed off unscientifically. Waste treatment and disposal sites can create health hazards for the neighborhood. Improperly operated incineration plants cause air pollution and improperly managed and designed landfills attract all types of vectors, insects and rodents that spread diseases such as dysentery, diarrhea etc which affects the health of human beings. The solid waste is also a great threat to the workers and for persons who come in direct contact with it. Direct handling of solid waste can result in various types of infectious and chronic diseases with the waste workers and the rag pickers being the most vulnerable. Improper disposal of solid waste may sometimes cause death to human beings through contamination of water and food materials. Direct dumping of untreated waste in rivers, seas, and lakes results in the accumulation of toxic substances in the food chain through the plants and animals that feed on it. Besides this the improper disposal of solid waste may produce bad odors, which destroys the beauty of nearby areas.

SOLID WASTE MANAGEMENT

Waste management is a problem in urban and rural areas. Many areas, particularly in developing countries, still have inadequate waste management; poorly controlled open dumps and illegal roadside dumping remain a problem. Such dumping spoils scenic resources, pollutes soil and water resources, and is a potential health hazard to plants, animals and people. According to the United Nation's Centre for Human Settlements, only between 25 and 55 per cent of all waste generated in large cities is collected by municipal authorities. At least 60 per cent of the countries that submitted national reports to the United Nations in advance of the 1992 Earth Summit said that solid waste disposal was among their biggest environmental concerns.

The importance of proper solid waste management is one of the prime functions of the civic body, as improper management of solid wastes is a cause of much discomfort. Since waste management is the fundamental requirement for public health, Article 48-A of the Indian Constitution establishes the responsibility of the state to manage these wastes properly. CPCB with the assistance of NEERI has conducted a survey in 59 cities (35 metro cities and 24 state capitals) in year 2004-05 and reported that 39031 tonnes of solid waste per day have been produced in India. On the basis of available data, it is estimated that the ten major metropolitan centers in India are presently producing 25364 tones of solid waste per day as shown in table 2 (*www.cpcb.nic.in*).

Table 2. Urban waste situation in some major Indian cities.

Major cities	Waste Quantity (Tonnes per day)
Surat	1000
Pune	1175
Kanpur	1100
Ahmedabad	1302
Hyderabad	2187
Banglore	1669
Chennai	3036
Kolkata	2653
Delhi	5922
Mumbai	5320

Source: http://cpcb.nic.in

Waste minimization is a methodology used to achieve waste reduction, primarily through reduction at source, but also including recycling and re-use of materials. The benefits of waste minimization are both environmental and financial and wide in their coverage. Management of solid waste may be defined as that discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that it is accordance with the best principles of public health, economics, engineering, conesrvation, aesthetic, and other environmental considerations. Solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in the whole spectrum of solutions to problems of solid wastes (Tchobanaglous *et al.,* 1997). To implement proper waste management, various aspects have to be considered such as:

- Source reduction
- Onsite storage
- Collection and transfer
- Processing techniques
- Disposal

The following flow chart shows the interrelationship between the functional elements in solid waste management (Fig 1).

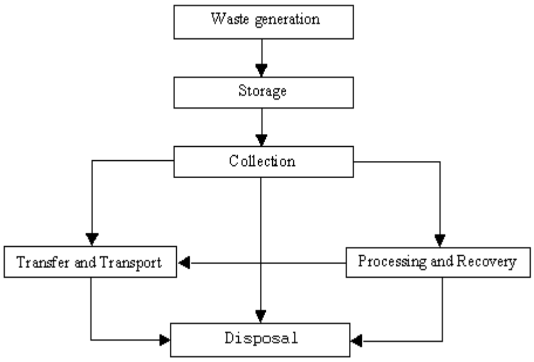

Fig 1. Interrelationship between the functional elements in solid waste management.

WASTE DISPOSAL OPTIONS

Final destination of solid waste in India is disposal. Most urban solid waste in Indian cities and towns is landfilled and dumped. A wide range of disposal options in many developing countries is available and some of them are listed below:

Non-engineered disposal

This is the most common method of disposal in low-income countries, which have no control, or with only slight or moderate controls. They tend to remain for longer time and environmental degradation could be high, include mosquito, rodent and fly breeding, air, and water pollution, and degrading of the land. In many Indian cities, open, uncontrolled and poorly managed dumping is commonly practiced, giving rise to serious environmental degradation. More than 90% of Solid waste in cities and towns are directly disposed off on land in an unsatisfactory manner (Sharholy *et al.*, 2008).

Sanitary Land filling

Sanitary landfill is a fully engineered disposal option, which avoids harmful effects of uncontrolled dumping by spreading, compacting and covering the wasteland that has been carefully engineered before use. Through proper site selection, preparation and management, operators can minimize the effects of leachates (polluted water which flows from a landfill) and gas production both in the present and in the future. In this process the waste is disposed and is covered with a layer of soil. The compact layer of soil restricts continued access to the waste by insects, rodents and other animals. It also isolates the refuse, minimizing the amount of surface water entering into and gas escaping from the waste (Turk, 1970). Sanitary Landfilling is a necessary component of solid waste management, since all other options produce some residue that must be disposed of through landfilling. However, it appears that landfilling would continue to be the most widely adopted practice in India in the coming few years, during which certain improvements will have to be made to ensure the Sanitary landfilling (Kansal, 2002; Das *et. al.*, 1998).

Composting

Composting is a biological process of decomposition carried out under controlled conditions of ventilation, temperature, moist-ure and organisms in the waste themselves that convert waste into humus-like material by acting on the organic portion of the solid waste. If carried out effectively, the final product is stable, odour-free, does not attract flies and is a good soil conditioner. Comp-osting is considered when biodegradable waste is available in considerable fraction in the waste stream and there is use or market for compost. This is a popular technique in Europe and Asia, where intense farming creates a demand for the compost (Schneider, 1970). Centralized composting plant for sector may only be undertaken if adequate skilled manpower and equipment are available, hence at household level and small level composting practices could be effective which needs the people's awareness. Many large-scale compost plants with capacities of ranging from 150 to 300 tonnes/day were set up in the cities of Bangalore, Baroda, Mumbai, Calcutta, Delhi, Jaipur and Kanpur during 1975-1980 (Sharholy *et al.*, 2008). Now, about 9% of solid waste is treated by composting (Gupta *et al.*, 2007; Srivastava et al., 2005). After composting the final product obtained is called compost, which has very high agricultural value. It is used as fertilizer, and it is non-odorous and free of pathogens (Ahsan, 1999; Khan, 1994).

Incineration

In Incineration combustible waste is burned at temperatures high enough (900-1000 ^{0}C) to consume all combustible material, leaving only ash and noncombustible to dispose off in a landfill. Under ideal conditions, incineration may reduce the volume of waste by 75% to 95% (Schneider, 1970). Incineration may be used as a disposal option, only when land filling is not possible and the waste composition is of high combustible (i.e. self-sustaining combustible matter which saves the energy needed to maintain the combustion) paper or plastics. It requires an appropriate technology, infrastructure, and skilled manpower to operate and maintain the plant. In Indian cities, Incineration is generally limited to hospital and other biological wastes. This may be due to the high organic material (40-60%), high moisture contact (40-60%) and low calorific value content (800-1100Kcal/Kg) in solid waste (Kansal, 2002; Joardar, 2000; Bhide & Shekdar, 1998).

Incineration of urban waste is not a clean process. It may produce air pollution and toxic ash. For example, incineration in the United States apparently is a significant source of environmental dioxin, a carcinogenic toxin and a controversy over incineration has resulted (Thomas & Spiro, 1996). Smokestacks from incinerators may emit oxides of nitrogen and sulfur that lead to acid rain; heavy metals such as lead, cadmium, and mercury; and carbondioxide that is related to global warming. In modern incineration facilities, smokestacks are fitted with special devices to trap pollutants, but the process of pollutant abatement is expensive (Botkin & Keller, 2000).

Pyrolysis

In Pyrolysis, the chemical constituents and chemical energy of some organic wastes is recovered by destructive distillation of the solid waste. It is a form of incineration that chemically decomposes organic materials at high temperature in the absence of oxygen. Pyrolysis typically occurs under pressure and at operating temperatures above 430 °C. In practice, it is not possible to achieve a completely oxygen-free atmosphere. Because some oxygen is present in any pyrolysis system, a small amount of oxidation occurs. If volatile or semi-volatile materials are present in the waste, thermal desorption will also occur. Organic materials are transformed into gases, small quantities of liquid, and a solid residue containing carbon and ash. The off-gases may also be treated in a secondary thermal oxidation unit. Particulate removal equipment is also required. Several types of pyrolysis units are available, including the rotary kiln, rotary hearth furnace, or fluidized bed furnace. These units are similar to incinerators except that they operate at lower temperatures and with less air supply.

Vermicomposting

Municipal solid waste is highly organic in nature, so vermicomposting has become an appropriate alternative for the safe, hygienic and cost effective disposal of it. In this method earthworms feed on the organic matter present in the solid waste and convert into casting (ejected matter) rich in plant nutrients. Vermicomposting has been used in various cities of India like Hyderabad, Bangalore, Mumbai and Faridabad. Experiments on developing household vermicomposting kits have also been conducted (Sharholy *et al.,* 2008).

Reuse and Recycling of waste materials

Recycling is the reprocessing of discarded materials into new useful product. The process of reusing of cans can save money. Recycling of paper will reduce of cutting of tress. Reuse of metals will reduce the mining activities. In India about 40-80% of plastic waste is recycled compared to 10-15% in the developed nations of the world. However the recovery rate of paper was 14% of the total paper consumption in 1991, while the global recovery rate was higher at 37% (Pappu *et al.,* 2007; CPCB, 2004).

During most of human history, the approach to waste management in many cultures and civilizations was the recovery of materials. Only around the turn of the twentieth century the emphasis shifted from recovery to disposal. During the nineteenth century there were pioneering efforts in England to minimize wastes as a way to improve industrial competitiveness (http://segate.sunet.se/archives/rt-w10.html). Waste management in developing countries like India, must emphasize and be linked to the creation of jobs, poverty alleviation and community participation. There is increasing evidence that community-based approaches to waste management can promote a more sustainable development. Grassroots efforts can be more successful than top-down programs created by bureaucrats or experts with little or no community participation. To minimize the solid waste generation adopt the policy of 4R's.

THE POLICY OF 4R's

Refuse

Instead of buying new containers from the market, use the ones that are in the house. Refuse to buy new items though you may think they are prettier than the ones you already have.

Reuse

Do not throw away the soft drink cans or the bottles; cover them with homemade paper or paint on them and use them as pencil stands or small vases.

Recycle

Use shopping bags made of cloth or jute, which can be used over and over again. Segregate waste to make sure that it is collected and taken for recycling.

Reduce

Reduce the generation of unnecessary waste, e.g. carry your own shopping bag when you go to the market and put all your purchases directly into it.

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