India, with a population of more than one billion, is the world’s second-most-populated country. If present trends continue, India will overtake China as the country with the largest population by 2035. About 30 per cent of India’s population (more than 300 million) lives in cities. The country has experienced rapid population growth, and if present trends continue, more than half of all Indians will be urban dwellers in 2020 and over 30 per cent of urban dwellers will be slum dwellers and squatters. Indeed, with so many people, it is hardly surprising that India produces 42 million tonnes of municipal solid waste (MSW) every year. The problem is that collection efficiency ranges between 50 and 90 per cent of the waste generated, and as India’s population continues to grow, so will its MSW generation.
At present, MSW management is still a serious problem in most of the cities in India. Only a fraction of the wastes generated are collected, and those that are collected are disposed of in open dumps on the outskirts of cities. Sanitary landfills are practically non-existent in India except for a few that have recently been constructed. Insufficient collection and inadequate disposal create pollution problems, such as the emission of methane gas (which contributes to global warming), and pose risks to human health and the environment. The country’s urbanization and population growth tend to contribute to further deterioration of this situation.

The National Environmental Engineering Research Institute (NEERI), a constituent laboratory of the Council of Scientific and Industrial Research (CSIR), is dedicated to environmental science and engineering for sustainable development, with the aim of providing innovative and effective solutions to environmental and natural resource problems. One of its goals is to improve solid waste management in Indian cities by examining recent experiences in various urban areas and using them as models to improve MSW management. In many of the cities, an integrated approach for MSW management is being planned by incorporating various techniques of waste management, which in turn leads to improvement in the system. Other municipalities are successfully replicating the same models. The failure of some methods applied by a city, the lessons learned, and the precautions taken in adopting new MSW technologies in other cities were analysed by NEERI for this project.

**Background and Justification**

Indian urban dwellers generate 0.2-0.6 kg per person per day of solid wastes, resulting in a national total generation of nearly 105,000 metric tonnes of solid wastes daily. The country’s largest cities collect between 70 and 90 per cent of total wastes generated while smaller cities and towns usually collect less than 50 per cent. Uncollected wastes accumulate on the streets, public spaces and vacant lots, sometimes creating illegal open dumps. Residents also throw their wastes into the nearest stream or burn them. Uncollected wastes and residents’ actions to deal with them create pollution problems and pose risks to human health and the environment.

Waste collection methods are inefficient and vary from city to city and even within each city. Door-to-door collection is not widely practised. This collection method exists where residential associations hire private scavengers to perform it. Wastes from narrow residential and commercial lanes and areas with high traffic are often not collected. Even though the Supreme Court of India ruled in 1986 that municipalities should offer door-to-door collection, progress to comply with the existing MSW rule has been slow.

Wastes are often scattered by human scavengers searching for recyclables as well as by cows, rodents, stray dogs, etc. searching for food. When garbage is scattered, it must be swept
by the sweepers, picked up, loaded onto their collection vehicles (wheelbarrows, carts and various types of other vehicles) and taken to the community waste storage sites. Each neighbourhood has at least one masonry unit where residents and/or street sweepers bring the wastes for storage. Most often, street sweepers simply dump the wastes on the floor of these structures.

At the structures, human scavengers salvage materials, and cows, dogs, rodents and goats look for food to eat. Even though human and animal scavenging reduces the amount of wastes that need to be transported and disposed of, these activities present health risks to the animals and to human health. Cities usually lack recycling programmes but a large number of waste pickers recover recyclables from wastes. It has been estimated that up to one million individuals make a living from scavenging activities throughout India. Scavengers recover any materials and items that can be reused and recycled: paper, plastics, metals and so on. Several cities have composting programmes but they often process mixed wastes, which produce low-quality compost. The composting plants in Delhi use the windrow method but piles are formed of mixed wastes without previous separation of organic and inorganic materials.

Cities spend $11.60 to $34.90 per metric tonne on waste collection, transportation, treatment and final disposal. Most of this cost is spent on collection (60-70 per cent) while transportation requires 20-30 per cent and final disposal less than 5 per cent. For example, the national capital, New Delhi, spends 71 per cent on collection, 26 per cent on transportation and 3 per cent on final disposal. Virtually all the country’s collected wastes are disposed of at open dumps, which are the cheapest option available. Despite their low cost, open dumps are a source of land, water and air pollution as well as a public health hazard. The prevailing method of open dumping is a major source of environmental pollution, as presented in figure 1.

![Figure 1. Solid waste status in open dumps.](image1.jpg)

Moreover, it has become increasingly difficult to identify new sites for disposal owing to public opposition, scarcity and the high cost of land. The waste segregated by rag pickers is depicted in figure 2.

![Figure 2. Rag pickers at landfill sites.](image2.jpg)

Open dumping of solid wastes generates various environmental and
health hazards, as noted earlier. The decomposition of organic materials produces methane, which can cause fires and explosions and contributes to global warming. Fires periodically break out in open dumps, generating smoke and contributing to air pollution. Fires at open dumps often start spontaneously by the methane and heat generated by biological decomposition. Dump managers in some cities deliberately set periodic fires at the dumps in order to reduce the volume of the wastes, which allows more wastes to be disposed of there and thus extends the life of the dumps. Human scavengers may also cause intentional fires since metals are easier to spot and recover among the ashes after the fires than among piles of mixed wastes. Food leftovers and kitchen wastes attract birds, rats, flies and other animals to the dumps. Animals feeding at the dumps may transmit diseases to humans living in the vicinity. The biological and chemical processes that occur in open dumps produce strong leachates, which pollute surface and groundwater. Biodegradation of organic materials may take decades, which may limit the future use of the land on which open dumps are located. Slums and squatter areas often suffer from sporadic or no waste collection at all. Many low-income individuals lack toilets and urinate and defecate on the streets or open spaces. Open defecation and disposal of sewage and garbage from such settlements need proper attention. A large number of cows roam the streets in Indian cities, and the dung that they generate is not properly managed.

MSW management is a part of public health and sanitation and is entrusted to the municipal government for execution. Presently, the systems are assuming larger importance due to a population explosion in municipal areas, legal intervention, emergence of newer technologies and rising public awareness regarding cleanliness. Solid waste management systems exist in most of the urban centres; however, these systems have yet to emerge as a well-organized practice. Although the solid waste characteristics vary quite significantly in different urban centres, there is a meagre effort to tailor the system configuration to the waste characteristics. The major deficiencies associated with the system are as follows:

- rapidly increasing areas to be served and quantity of waste;
- inadequate resources;
- inappropriate technology;
- disproportionately high cost of manpower;
- societal and management apathy; and
- low level of efficiency of the system.

Except in the metropolitan cities, solid waste management is the responsibility of a health officer who is assisted by the engineering department in the transportation work. The activity is mostly labour intensive, and two to three workers are provided per 1,000 residents served. The municipal agencies spend from 5 to 25 per cent of their budget on solid waste manage-
ment, which is Rs. 75-250 ($1.50-$5.00) per capita per year. Normally, a city of 1 million people spends around Rs. 10 crores ($2 million) for this activity. In spite of this expenditure, services are not provided to the desired level.

The environmental and health hazards caused by the unsanitary conditions in the Indian cities were epitomized by the episode of plague in Surat, Gujarat, India in 1994. That triggered public-interest litigation in the Supreme Court of India. Based on the recommendations of the committee set up by the apex court in that public-interest litigation, the Government of India framed the Municipal Solid Wastes (Management and Handling) Rules, 2000, under the Environmental Protection Act, 1986. One of the major requisites of these rules was to establish a door-to-door garbage collection system in the cities. Nagpur, which is located in the centre of India, has taken the initiative in implementing MSW Rules, 2000, by introducing 100 per cent door-to-door garbage collection, which has significantly improved the environment and the efficiency of recycling from waste and created jobs for 1,600 people from the poorest backgrounds.

In addition, a “zero waste management scheme” was initiated in 1989 that has been set up, run and financed by the residents themselves. This model has been a success so the study by NEERI aimed at learning from two communities – Hyderabad and Chennai – that have implemented this model.

Description

In view of the aggravated problem of municipal solid waste (MSW) management in India, NEERI advocated for a source-specific solution for the waste management system in India through the research carried out in various cities while developing a long-term plan for MSW management for various cities. For that, research work was undertaken with the sponsorship of international and national government agencies such as State Pollution Control Boards (SPCBs), the Central Pollution Control Board (CPCB), the local Municipal Corporation and the Ministry of Urban Development to carry out the laboratory and field study and questionnaire survey of the different municipalities in India. The aim was to diagnose the existing situation, make recommendations for a better system and advocate successful good practices/field application to improve the prevailing situation of MSW management. The CPCB is the central government body that looks after environmental aspects all over India while SPCBs are operating and looking after environmental aspects in particular States. Finally, local bodies look after cities, towns and zones and report to SPCBs, which in turn report to the CPCB.

Researchers at NEERI examined the MSW management systems in various municipalities and the different methods used, such as where waste was being collected, the sweeping of streets and public spaces, the provision of litter bins and waste storage depots, the trans-
portation of waste, and the processing and disposal of waste. The Swachata Doot approach is a scientific and innovative approach for MSW management that includes the following aspects:

- daily door-to-door garbage collection;
- waste segregation;
- garbage lifting and transportation;
- employment generation; and
- awareness-building.

The collection and segregation of MSW constitute a primary requirement for implementation of MSW Rules, 2000. The primary collection of garbage is important to prevent littering of waste on the streets. As per the MSW guidelines, waste must be collected in segregated form so that it can be recycled to the extent possible by the adoption of suitable technology. This recycling will minimize the burden on landfills. Though doorstep collection of segregated waste is important for MSW management, it is not carried out by many of the municipal bodies in the country since they are lacking in financial resources or the expertise to comply with those rules and they often make little effort to revise outdated and deficient waste management systems.

As the authorities were hardly able to provide cost-efficient service to citizens, one possibility was to outsource solid waste management by putting in charge professional private organizations such as the Centre for Development Communication (CDC). The key concept is a daily door-to-door collection of segregated domestic waste but the model includes all aspects of solid waste management from waste generation to waste processing (e.g., recycling and vermi-composting) and final disposal. The end consumer is both the main contributor and the main beneficiary since he/she should segregate the waste instead of littering it and, in turn, profit from the cleanliness of the city and the creation of a new awareness that CDC work is generating. Presently, the Swachata Doot project is being successfully implemented in several cities of India such as Nagpur, Maharashtra.

Researchers considered the technical aspects of MSW management, concerned with the planning, implementation and maintenance of collection and transfer systems; waste recovery; and final disposal. Technical facilities and equipment must be designed and selected with careful regard to their operating characteristics, performance, maintenance requirements and expected life-cycle costs. Close attention must be paid to preventive maintenance, repair and availability of spare parts. The design of transfer facilities and equipment must match the characteristics of local collection systems and the capacity of existing disposal facilities. Local collection systems must be designed with the active participation of the communities concerned. Informal waste recovery and scavenging may be rendered more productive through support measures and appropriate technical design of the waste management systems. Public-sector involvement in waste recovery and/or leasing of waste-recovery rights to
private-sector enterprises may be considered. The most appropriate method of final disposal in developing countries is nearly always the sanitary landfill. To minimize their environmental impact, landfills must be carefully sited, correctly designed and well operated. Sources of hazardous waste materials must be identified, registered and targeted for appropriate management; special attention needs to be paid to infectious health-care wastes.

The effectiveness of the "zero waste management model", introduced in Chennai and Hyderabad in the 1980s, was also examined. The aim of an area-based organization implementing zero waste management is to clean the neighbourhood by organizing a door-to-door collection service of household waste and sweeping of the streets, to alleviate the burden on land for dumping by recycling as much waste as possible locally, and to give a recognized social status to local waste pickers by employing them to do the job. Ninety-five per cent of the household wastes by weight are potentially recyclable. Indeed, measurements taken during the present study and confirmed by figures published by the Municipal Corporation of Chennai indicated that 15 per cent of household refuse was inorganic recyclable material, which could be sold to the well-established recycling industry, and 80 per cent of household refuse was organic matter that could be composted. If these fractions could be separated at source and processed locally, only 5 per cent of the household waste load would need to be handled by the Municipal Corporation.

The scheme is set up, run and financed by the area-based organization itself. A committee of dedicated members of the community takes charge of the management of the workers and the accounts; they collect the monthly fees paid by each household, link to the local authorities and supervise the operations. Regular meetings are held. The residents fund the scheme and participate in segregating their waste into organic and inorganic fractions and stop littering on the streets. The equipment and infrastructure needed are tricycles as collection vehicles and land for further segregation and composting of the green wastes. The inorganic recyclable items are sold to local dealers. Ideally, the revenue generated from the sales of the recyclable items and compost, on top of the funds collected from the participating households, is enough to sustain the service, including operation and maintenance.

**Participants**

The Government of India has initiated guidelines to encourage projects involving public-private partnership to tackle the aggravated problem of MSW in the country. Many of the projects on solid waste management are being carried out with a public-private partnership programme. Projects are selected based on a build-operate-transfer (BOT) basis. Regional collaboration along with international partners, such as Indo-German collaboration and Indo-European Union collaboration, is booming. These col-
laborative efforts are aiming to improve the very inadequate existing MSW management with suitable technology transfer and sharing of ideas.

**Replicability**

MSW management systems are site-specific. They also depend on geographical regions and climatological conditions. However, the systems developed for a particular region or city are replicable in other cities provided that the local scenario and waste characteristics for that specific region are taken into consideration. Moreover, the innovative experience is quite relevant for developing the system in other regions, and this is being done in Bengaluru, Mumbai, Varodara and other big cities of India including the State capitals of northeastern hilly regions.

Owing to intervention from the Supreme Court of India in view of many public-interest litigations in different cities and non-compliance with MSW (Management and Handling) Rules, 2000, the Government of India has created different committees to achieve a good impact in this sector. The Government has proposed a heavy budget for MSW management. A separate committee is revising the MSW Rules in India, with the revision likely to come in 2013. The committee is looking to change the MSW rules in India considering the various innovations in MSW management being undertaken in different parts of the country in general and at the global level in particular. The Government of India is placing more emphasis on collaboration with multination-

**Impact**

The innovative approach for tackling MSW management in India is quite sustainable and the new methods tried and tested should reduce the amount of waste produced in urban areas. The city of Shimla has opted for a door-to-door collection system with different aspects in which some staff of the Municipal Corporation collect the garbage from two different biodegradable and non-biodegradable bins. This helps to reduce the aesthetic problem and revenue collected from this practice leads to maintaining the existing sustainable solid waste management practices for this city. In Visakhapatnam, the Municipal Corporation has started with garbage collection through the Janachaitanya and Subram schemes. According to these schemes, one needs to segregate waste into biodegradable and non-biodegradable components. Municipalities would lift the waste within 24 hours of a complaint. Similarly, debris would be removed within one week of a complaint. Also, if any garbage bin is to be replaced, it would be replaced within 15 days. This has led to sustainable solid waste management in the city. In addition, people are happy with the efficiency of the system.
LESSONS LEARNED

The scheme in Hyderabad was less ambitious in its overall objectives and focused on the provision of a waste management service, using the opportunity to provide local employment to a socially deprived fraction of the population. The scheme in a middle-class area of Chennai, although pioneering in its approach, suffered from diseconomies of scale and lack of social integration, making it less viable in the medium to long term. Both schemes suffered from a lack of community involvement, motivation and political support, which threatens the long-term sustainability of the enterprise. The research concluded that the role that communities can realistically play in the management of their own waste depends on the local context. The system advocated requires significant local resources, and political and technical support that are hard to find and sustain without strong local leaders. Another model set up in the city of Visakhapatnam was finally introduced as an alternative. It is based on triangular contracts between the municipality, the residents and microenterprises and may provide a good solution in dealing with the technical and commercial aspects that communities find difficult to handle.

Researchers learned from the innovative experience that public awareness is vital for successful implementation of the innovations in the MSW management sector in India. Owing to the Government's initiative, municipalities are now setting up processing plants for MSW and the facilities are growing at a faster rate, which should improve MSW management.

FUTURE PLANS

The involvement of NEERI in solid waste management activities in India emphasizes that the improvement of the system needs to be developed and address the following issues:

- financial weakness of managing agencies;
- difficulties in changing the prevailing nature of infrastructure service;
- low recycling potential of waste material;
- lack of availability of skilled labour; and
- societal and managerial apathy.

Against this backdrop, the system could be improved through an integrated approach covering many other issues than the technological system, as presented in figure 3.

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**Figure 3.** Integrated solid waste management plan for MSW management.
It is a vital, ongoing and large public service system, which needs to be efficiently provided to the community to maintain aesthetic and public health standards. Municipal agencies will have to plan and execute the system in keeping with the increasing urban areas and population. Currently, the mixed waste is being disposed of unscientifically in open dumps. There must be a systematic effort to improve various factors such as institutional arrangements, financial provisions, appropriate technology, operations management, human resource development, public participation and awareness, and a policy and legal framework for an integrated solid waste management system.

To achieve cleanliness, it is necessary to design and operate an efficient MSW management system. Public cooperation is essential for the successful operation of such a system. MSW management should focus on the environmentally sound management of biowastes and other biodegradable materials. Governments at both the senior and local levels can assist in this area.

The MSW management system was adopted a century ago as part of a public policy to protect public health and safety. In the intervening years, MSW management contributed to the unsustainable growth of material flows in advanced industrial economies and it is not configured to provide effective management of either product or non-product wastes. It is clear that the wastes that people consider to be unwanted can be considered assets if an integrated approach is applied for their proper management. The focus is on source separation of wet and dry waste.

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