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Exploring Possibilities of Achieving Sustainability in Solid Waste Management

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The solid waste management scenario in the recent years has shifted towards a more sustainable approach. This paper brings in to focus the waste management methods that can be adopted using Bangalore as case study, in order to achieve economic viability and explores the sustainable options that conserves both natural and man-made resources and averts ecological risks. Bangalore, the Garden City of India with a population of 6 million is facing the daunting task of handling 3613 tonnes of municipal solid waste per day. Added to this are the constraints that are faced by the authorities such as poor political back up, inadequate infrastructure, insufficient funds and lack of public support. Attempts have been made to clear wastes by door to door collection method, introduction of push carts, which separate biodegradable wastes from non biodegradable wastes, deployment of auto tippers to clear slum wastes etc. under the guidance of Bangalore Agenda Task Force (government appointed body) and Bangalore Mahanagara Palike (city municipal corporation). Integrated waste management system is proposed as an option, which include collection, transport and processing of wastes in an environmentally sound way. The methods to overcome constraints in waste management and the future plans and actions that will bring about a significant change in the current waste management practices are also discussed in the paper.

Key Words: *Door to door collection; pushcarts; auto tippers; integrated waste management*

Introduction

Bangalore is home to 6 million people and is one of the fastest growing cities in India. The city is facing acute problems related to solid wastes. This is despite the fact that the largest part of the municipal expenditure is allotted to management of municipal solid wastes. The current waste generation in Bangalore is 3613 tonnes per day and the number is likely to grow in the next few years due to the increasing population and will present a formidable challenge to authorities unless an integrated approach is taken. The objective of this paper is to present an overview of the current waste management practices in Bangalore and to discuss suitable methods to overcome the constraints. This paper was built up on various interviews conducted with the authorities and of experiences and observations.

An Overview of the Current Waste Management Practices in Bangalore :

Bangalore City is divided into 100 administrative wards, which have been further divided into 273 health wards for functional convenience. Of these, 147 health wards are under private contract system and the remaining 126 health wards are managed through Pourakarmikas (municipal sweepers) of the Corporation. Except for few wards in Bangalore there is no door-to-door collection service in Bangalore. The areas not served are mostly unincorporated or illegal settlements and slum areas with small and inaccessible streets. By contract more prosperous areas are better served, kept clean and swept on a regular basis.

Waste generation : The waste generation in Bangalore is given in Table 1:

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Table 1: Waste generation in Bangalore[1]

Stakeholders	Quantity of Waste (tonnes/day)	%
Households	650	18
Commercial Establishments	1436	39
- Markets	369	
- Hotels	1067	
Institutes	128	4
- Hospitals	20	
- Offices	16	
- Educational institutions	92	
Industries	1399	39
Total	3613	100

As evident from the table, wastes from commercial establishment make up for the bulk of the total wastes. Although industries also generate a significant amount, it was analysed that most of this is recovered for recycling and reuse and only a small percentage find it's way into the city waste stream.

A typical waste composition for major Indian cities is given in Table 2.

As evident from the Table above, the composition of organic waste is high in all the cities and Bangalore ranks the highest. Waste densities and moisture contents are high, which require different technology and management system. High organic content and low biodegradable waste are typical of Indian cities and hence incineration is a less appropriate option.

Waste storage : Waste is stored in 14,000 bottomless and lidless cement bins having 0.9 meters diameter and 0.6 cubic meter storage capacity and large masonry bins for depositing waste placed at a distance of 100-200 meters. Recently 55 metal containers have been placed at different parts of the city. However not all parts of the city are provided with storage systems. In some places, the wastes are just deposited on roadsides.

Waste collection and transport : Collection of waste is either done by Bangalore Mahanagara Palike (BMP) or by private contract system. In December, 2001 BMP and Bangalore Agenda Task Force (government appointed body) through a joint initiative established a public private partnership, by launching a sustainable cleanliness program called 'Swachha Bangalore'. Twenty five percent of the city is served under this scheme. Swachha Bangalore is mainly door to door collection of wastes using pushcarts (Plate 1). There are totally 2105 pushcarts in operation in Bangalore, which consists of 4 buckets that are used to store dry wastes and wet wastes separately. Swachha Bangalore scheme also covers selected slum areas and auto tippers have been deployed for collection of wastes (Plate3). There are 6500 pourakarmikas in charge of door to door collection, sweeping, emptying dustbins and clearing black spots. They arrive at a designated spot to transfer the waste to the truck. Trucks have a capacity of 4-5 tonnes capacity and are either openbodied or covered with a mesh (Plate 2). The ratio of truck to ward is 4:20. Other collection systems consist of bullock carts, tricycles etc. Collection is sometimes difficult due to narrow roads and due to this waste is not picked on time causing unsanitary conditions. There are no transfer stations in Bangalore.

Table 2. Composition of urban solid waste in Indian cities (percentage by weight)[2]

City	Paper	Metals	Glass	Textiles	Plastic[1]	Ash and dust	Organics	Others[2]
Chennai	5.90	0.70	-	7.07	-	16.35	56.24	13.74
Delhi	5.88	0.59	0.31	3.56	1.46	22.95	57.71	7.52
Kolkota	0.14	0.66	0.24	0.28	1.54	33.58	46.58	16.98
Bangalore	1.50	0.10	0.20	3.10	0.90	12.00	75.00	7.20
Ahmedabad	5.15	0.80	0.93	4.08	0.69	29.01	48.95	10.39
Mumbai	3.20	0.13	0.52	3.26	-	15.45	59.37	18.07

1 Includes rubber and leather

2 Includes bones, stones and wooden matter

Plate 1. Pushcart

Plate 2. Waste transfer

Plate 3. Auto tipper

Transportation of wastes to disposal site is done in two ways through the same trucks.

- by engaging 82 trucks of the corporation;
- through contractors by engaging 129 vehicles for layouts and markets and 72 vehicles on contract for transportation of waste.

The corporation also has 13 dumper placers for transporting metallic containers of 2.5 to 3 tonnes capacity and 6 minicompactors for transportation of wastes.

Waste processing and recovery : The method adopted to process waste is composting. Karnataka Compost Development Corporation handles 120 metric tonnes of raw garbage/day in the yard. Out of 100 tonnes of raw garbage, 55 tonnes of compost is obtained. Due to constraints of land, finance and demand, the facility can handle only 120 tonnes of wastes. As such out of the 369 markets in and around the city, only 2 have been accepted for composting. Vermicomposting is also practised to handle a portion of the waste. Dry wastes such as plastic, rubber, glass and other commodities are later disposed off.

Waste disposal : Disposal is the final stage of waste management system. About 90% of the municipal wastes collected by the civic authorities in Indian cities are dumped in low-lying areas outside the city/town limits. The waste disposal trends in major Indian cities are as given in Table 3.

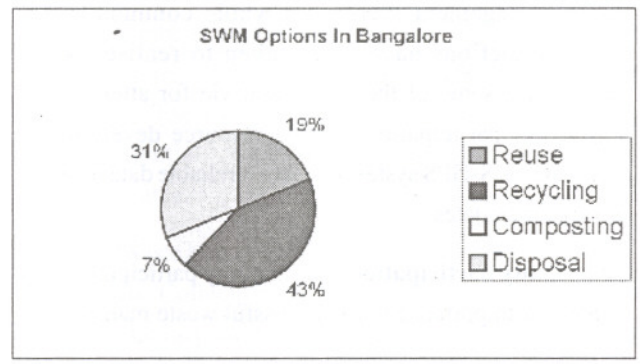
In Bangalore, the waste collected from roads and bins is directly transported to the final disposal site, usually an open dump. There is the likelihood of soil and groundwater

Table 3 : Waste disposal trends in India.

Waste disposal methods	*1971 – (40 cities)*	*1991 and 1999 (23cities)*
Land dumping	Almost all	89.8%
Composting	-	8.6 %
Others (pelletisation, vermi-composting)	-	1.6 %

contamination due to this practice. Birds (scavengers), vermin, insects and animals are attracted to the open dump for feeding and breeding. Since many of these may act as disease vectors, their presence may constitute a potential health problem. Sometimes plastic and other contraries are burnt, which may be hazardous to human health. Landfilling of wastes is not practiced in Bangalore.

Figure 4 provides information on the various SWM options in Bangalore. Recycling takes up 43% and is an area to be further exploited. Thirty one percent of the waste is disposed, which is mainly burnt or simply dumped in open spaces.



Issues of Importance :

SWM in Bangalore has definitely improved in areas of collection and transportation. However, waste processing and disposal is still a pressing problem to be dealt with. The informal network is very active in areas of recycling as this forms their only livelihood. However, there are various issues or constraints that have to be tackled to achieve significant strides in waste management. The issues that have to be addressed are summed up as follows:

- Effective public participation in segregation of recyclable wastes, primary collection of wastes and storage of waste at source.
- Provision of closed container and mobile waste storage depots and abolition of open waste storage sites.
- Processing of wastes for generating compost, power and other useful products.
- Disposal of wastes in an environmentally acceptable manner through establishment of sanitary landfill site.
- Improving the financial health of the local urban bodies.
- Encouraging private sector participation in waste management.
- Institutional strengthening and human resources development.
- Use of GIS and Remote sensing in assessing land pattern and land use
- Provision for enforcement of sanitation laws and rules.

Exploring Methods to Improve the System :

In order to improve the current solid waste management services it is essential to explore the various constraints or issues and to arrive at a suitable solution. Waste management involves a whole community and sufficient actions have to be taken to realise its full potentiality. Some of the issues that vie for attention are community participation, human resource development, promoting GIS-GPS systems to obtain reliable data on waste and legal mandates.

Community participation : Community participation is of paramount importance for a successful waste management system and requires considerable planning and management. First and foremost municipalities should enhance their understanding of what participation is and what it involves. It is essential that they develop an understanding of the objectives of participation, the potential for community participation (when participation can take place, in what form, at what stage of the service delivery process) and what makes participation more sustainable. Capacity building thus requires a more detailed understanding of the needs of the public, the extent of awareness among the public, the livelihoods and characteristics of the poor.

Municipalities can develop certain strategies to build capacity for community participation.

- Identification of people to be addressed such as residential areas and markets/commercial areas/offices/ banks etc.
- Identification of the areas in solid waste management where community participation is essential.
- Methods to reach the community.

A series of measures can be taken to bring about a change in public behaviour through public awareness programs (The Expert Committee, 2000). They are:

(i) Promote 'reduce, reuse and recycle' (RRR) of wastes among manufacturers and buyers.

(ii) Promote public participation in SWM systems adopted. Citizens should be made aware that wastes are not to be thrown on the streets, drains, water bodies, open spaces and also prohibit them from littering and open defecation. They should participate in primary collection of wastes, store wet and dry wastes separately at source and litterbins on roads and public places.

(iii) Provide information hotline.

(iv) Public education through group meetings, workshops, exhibitions, lecture series, panel discussions etc.

(v) Mass education through print media, use of cable TV/ radio/websites, use of cinema halls, street plays, posters, pamphlets, hoarding, primary school curriculum to cover the subject, resident associations etc.

Human resource development : Human resource development is very essential for internal capacity building for any organisation. Training motivation, incentives for outstanding services and disincentives for those who fail to perform are essential for human resources development. Knowledge of new technology and methods coupled with training at all levels is necessary[4]. Also, the corporators or elected members should be given appropriate orientation towards the need for modernisation of solid waste management system.

Another aspect, which has immense potential but is often overlooked, is harnessing waste pickers or rag pickers in the city. This is the informal sector, which accounts for 15% of the waste retrieved from streets and dumpsites for recycling purposes. Bangalore has an estimated 35,000 waste pickers, mostly women and children, who pick out discarded waste materials for a livelihood. Ragpickers around the city should be identified and encouraged to participate in waste collection. They can be elevated to 'waste collectors' and given badges or some identification documents so as to give some dignity to this much-neglected class. Ragpickers can be trained in door to door collection of wastes and in segregation of wet and dry waste. By imposing a monthly 'garbage' fee on the local residents, the waste pickers could generate an income. They can also earn an additional income by selling compost to the nearby farmers, and plastic and metals to the recycling industries. Since the number of pourakarmikas are not enough to handle the city's waste such training to waste pickers not only lightens the waste collection load but also rehabilitate the wastepickers.

GIS-GPS system for solid waste management system : Good municipal solid waste management practices requires collection of critical information which is not just for keeping the records up to date but used effectively for taking corrective measures as well as proper planning for the future. There is also a need for integration and assimilation of information from various levels of jurisdiction.

GPS-GIS systems can be powerful tools that can revolutionise the waste management systems in Bangalore. A management information system is required to manage large amount of spatial and attribute data related to the 273 wards and generate reports (daily, weekly etc) at various levels levels (city, zone, range etc.) with details of the waste, types of vehicles etc. In Bangalore, trucks are the only means of removing garbage and other waste materials from the city. These vehicles perform multiple trips in a day and it is essential to monitor and track these trucks to improve efficiency. In this regard, global positioning system (GPS) would be helpful and cost effective. It also helps in optimising truck routes thereby increasing the efficiency of the transport mechanism. Analysis of spatial data i.e. landuse and land cover pattern, transport network, collection network etc., along with information related to quantity related to quantity and quality of wastes (through GIS) enable the authorities involved in waste management to come out with feasible options[3].

These tools have been selected because 80% of information used by the health official has spatial components (city, zone, range and health ward level). These systems can be installed in BMP and zonal offices and establish monitoring centers in Bangalore. Training can be imparted to personnel in handling and updating the data.

GIS System for Waste Management in IISc Campus :

A GIS system has been developed for Indian Institute of Science campus[3]. The campus limits are enclosed within 13.01055^0 to 13.02083^0 latitude and 77.55944^0 to 77.57388^0 longitude. IISc is located in the northern part of Bangalore City having lush vegetation and campus has green canopy of trees covering the buildings. The main campus covers around 150 hectares. IISc has 40 departments, 2 banks, 1 school, 4 canteens, 1 restaurant, 4 guest houses, 400 faculty members, 800 supporting staff, 1500 students and 450 residential quarters representing a typical urban community. The institute generates all kinds of waste arising from residential, commercial, education, open area and vegetative area.

Waste bins of different types are distributed around the campus. Collection of waste is done by one truck, one tractor and mini pick up trucks. The frequency of collection

is 1 to 3 days. Collected wastes are dumped or burnt at common dumping site about 12 kms away from IISc. Regular street sweeping and roadside garden trimmings are done and wastes are dumped in bins. Transferring of waste to vehicles is done manually. The route followed is currently one convenient to the driver rather than from the collection point of view or from type and composition of wastes. All sensitive bins are not given priority in this method of collection. There is a need to evolve an optimal route evolved on the basis of waste composition and quantities generated in each bin.

Integrating spatial information along with corresponding attribute information was part of the study. Mapinfo 5.5 was used to create vector layers from the Survey of India (SOI) toposheets of scale 1:1000. Digitised vector layers include boundary, road network, building distribution, distribution of bins, open dumping sites, land

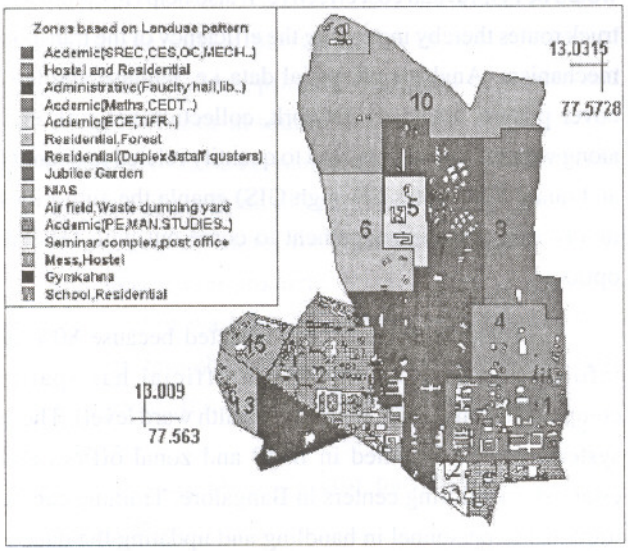


Fig. 1: Zones of IISc campus based on landuse pattern with spatial spread of buildings

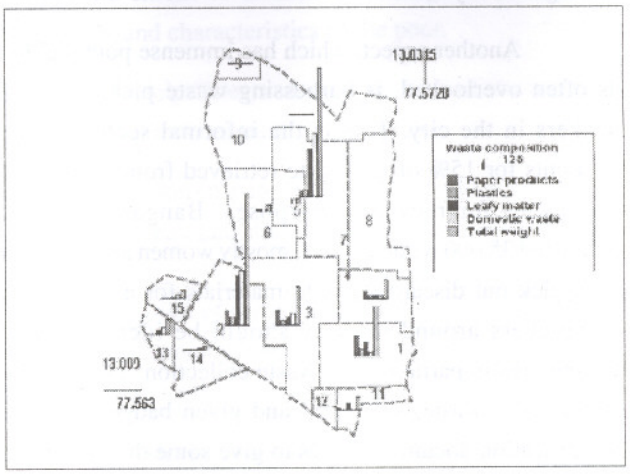


Fig. 2: Thematic maps with all zones and proportion of waste generated

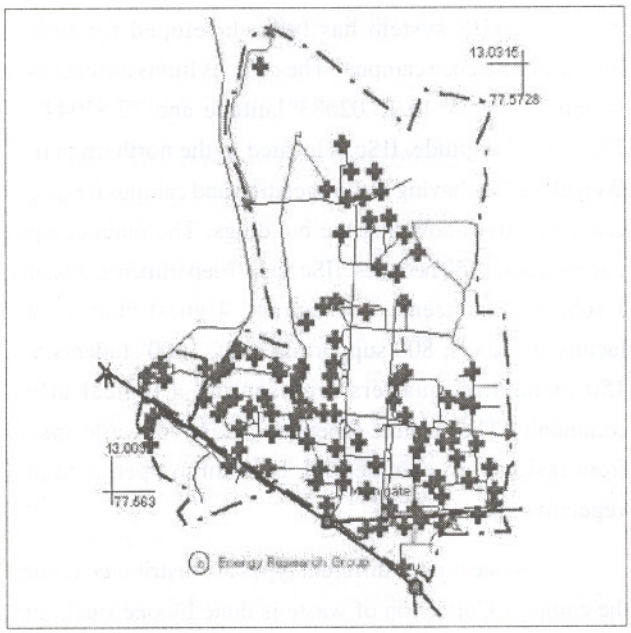


Fig. 3: Waste collection points

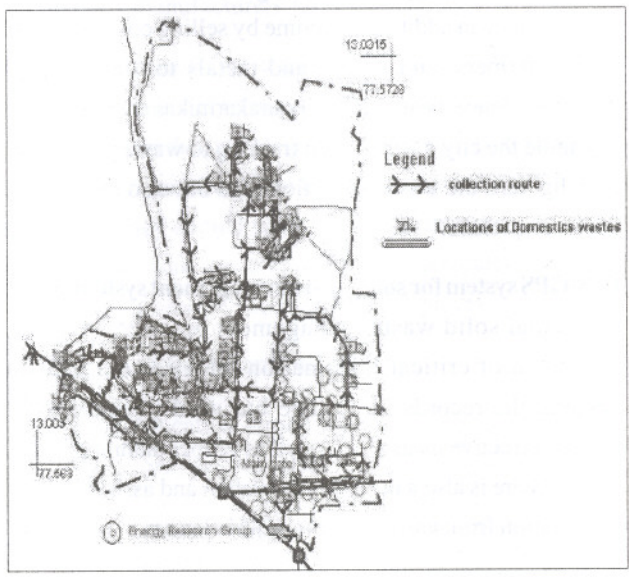


Fig. 4: Optimal route for collection vehicle

use and land cover, optimal routing etc. Figure 1 represents the land use of IISc campus.

Figure 2 depicts the proportion of waste generated in each zone. Figure 4 shows locations where wastes are collected. Studies were carried out at active bin sites. Figure 5 illustrates the optimal route for collection vehicle.

Theoretically provided optimal routing may not be apt, because of local conditions. Preference is given to collection of organic matter in order to avoid unaesthetic appearance, foul smell and animal problems. Optimal routing as shown in Figure 8 is arrived at, in such a way that zones with more domestic wastes are handled on priority while covering all zones and avoiding overlap. The corresponding micro routing for locations is felt as it is, considering experience of collection workers.

Legal Mandates : There are no environmental laws in the Karnataka Municipal Corporation Acts specifically pertaining to SWM. Solid waste management practices can never reach the desired level of efficiency until the public participates and discharges its obligation religiously. In order to improve solid management practices in urban areas it is necessary to incorporate suitable provisions in the state law to ensure public participation and providing for minimum level of solid waste management. Some of the proposed legal provisions are as follows:

- Prohibition and punishment for littering, open defecation and waste disposal on streets, etc.
- Duty of citizens not to mix recyclable/ non-biodegradable/ hazardous waste with organic waste.
- Duty of societies/associations/management of commercial complexes to clean their premises and to provide community bins that are covered and maintained in good condition.
- Duty of local body to provide and maintain 'waste storage depots'.
- Local body to provide uniforms, identity cards and protective equipments for sanitation workers and waste collectors.
- Duty of local bodies to clean all public streets, open public spaces and slum areas.
- Duty of local bodies to transport waste regularly to waste storage depots and to set up transfer stations in areas of narrow and difficult access.
- Duty of local bodies to set up landfill sites to dispose the rejects.

Planning an Integrated Waste Management System for Bangalore :

Bangalore City is in need of an effective solid waste management system to ensure better human health and safety. The system needs to be safe for workers and safeguard public health by preventing the spread of disease. In addition to these prerequisites, an effective solid waste manage must be environmentally sustainable and economically feasible.

It is quite difficult to minimise these 2 variables, environmental impacts and cost simultaneously. The balance that needs to be struck is to reduce the overall environmental impacts of waste management as far as possible, within an acceptable level of cost. An economically and environmentally sustainable solid waste management system is effective if it follows an integrated approach i.e. it deals with all type wastes from generation and its disposal.

The integrated approach must be based on a logical hierarchy of actions. The steps, in order of priority, which must be taken for Bangalore are as follows:

- Minimise the production of waste or source reduction
- Maximise waste recycling and reuse
- Encourage waste processing i.e. composting and biogasification
- Promote safe waste disposal

Minimise the production of waste or source reduction : Source reduction is a basic solution to the garbage glut: less waste means less of a waste problem. In many cases, source reduction can be done not necessarily by adopting a high

technology but also by inculcation of better personal habits in people. A reduction in the amount of wastes could be achieved by the following measures:

- Change of consumption pattern and lifestyle.
- Use of more recyclable materials.
- Practice of waste segregation at source.
- Change of manufacturing designs and packaging.

Studies by IIT, Mumbai, Confederation of Indian Industries (CII) etc. indicate that nearly 20 percent reduction in waste generation is possible through simple housekeeping measure requiring nil or marginal investment.

Waste reduction may occur through proper design of manufacture and packaging of products with minimum volume of material and longer useful life. Waste reduction may occur through selective reuse of products and materials. For example, the Ministry of Environment and Forest, Government of India has been establishing Waste Minimisation Circle (WMC) similar to KAIZEN of Japan in large and medium scale industries. Such circles can introduce a number of practices which can result in the minimisation of wastes which will ultimately lead to increased profits for the company[2].

Maximise waste recycling and reuse : This is the second best option in IWM. Though recycling of solid wastes is extensively practiced in Bangalore, the full official recognition of the need for promotion of recycling is yet to come. It is only in recent years that the role of this sector has been receiving some attention. Municipal authorities should actively support recyclables at source schemes by strengthening the informal sector, for example by the provision of sites for sorting of recyclables or perhaps by developing bonus schemes for the workers in the informal sector

There are considerable benefits to increasing solid waste recycling and reuse. Source separation and recycling of waste reduces the volume of wastes to be disposed. By promoting recycling as an alternative to existing forms of waste disposal, the authorities may gain net cost savings. Authorities may seek competitive bids as the recycling itself, by itself may be a profitable commercial operation thus generating them a net income. Also thousands of poor people support themselves and their families by directly or indirectly participating in waste collection and recycling. Many organisations in Bangalore such as Clean Environs, Waste Wise (Mythri foundation) and Centre for Environmental Education helps street children and other unemployed people to collect wastes from household and gives them a right to sell it too.

Encourage waste processing: Composting and biogasification : Organic waste in Bangalore constitutes 75 percent and is therefore amenable to composting and biogasification. It is a form of source reduction or waste prevention as the materials are completely diverted from the disposal facilities and require no management or transportation. Diverting such materials from the waste stream frees up dumping space needed for materials that cannot be composted.

Currently composting is provided for only 2 markets in Bangalore and this should be extended to other markets, hotels, restaurants, and households. Composting is considered viable only if there is a market for compost. Thus a better understanding of the process, benefits to the environment and public education can promote the practice of composting at least in cities where sites and skilled manpower are available, and markets can be developed. It is also essential to provide basic training and education of workers in technical, health, and safety aspects.

BMP can compost garden and park waste to reduce wastes for final disposal. Many resident associations in Bangalore have set up their own composting plants. Waste Wise Project of Mythri Foundation and the Centre for Environment Education has set up small scale vermicomposting plants for providing fertilisers in local parks.

Biogasification is an excellent option in handling the organic wastes. Once the MSW is segregated into fermentable and non-fermentable fractions, even at a >90% efficiency of sorting, MSW becomes amenable for biogas production. Biogasification has several advantages such as net energy output as well as low odour emissions during

treatment. Digested material, compost, with or without a post-composting stage, is safe for disposal as manure. A study carried out at ASTRA, IISc revealed that plug flow digesters are very good for biogasification of MSW as it is an excellent feedstock for biogas production and has a very high gas production (both gas production rate as well as specific gas production) to warrant viable decentralized treatment by anaerobic fermentation to biogas. It also requires very little pretreatment.

Promoting the safe disposal of wastes : Wastes are either burnt or dumped in open spaces. These practices should be abolished, as they are deleterious to human health and the environment. Landfilling occupies the lowest rung in integrated waste management. However landfilling of waste is a better option than dumping wastes in open spaces. It relies on containment rather than treatment (for control) of wastes. The purpose of land filling is to bury or alter the chemical composition of the wastes so that they do not pose any threat to the environment or public health. Landfills are not homogenous and are usually made up of cells in which a discrete volume of waste is kept isolated from adjacent waste cells by a suitable barrier. Commonly used barrier is a layer of natural soil (clay), which restricts downward or lateral escape of the waste constituents or leachate. Sanitary landfilling normally has a double liner to prevent leaching into the groundwater. Appropriate run-off controls, leachate collection and treatment, liners for protection of the groundwater (from contaminated leachate), biogas recovery mechanism (due to anaerobic decomposition of organic wastes landfill gas contains high percentage of methane), monitoring wells, and appropriate final cover design constitute integral components of an environmentally sound sanitary landfill. Proper and regular monitoring should be done at landfill sites.

Proposals for the Future :

Some of the proposed schemes for Bangalore are as follows;

- Taking into account the bulk wastes to be handled everyday, sanitary landfill sites have to be set up to dispose off the rejects after composting and landfilling.
- Regular monitoring of sanitary landfill sites involving local people in the team along with sanitary authorities.
- Applying technological solutions such as bio-gas recovery, composting, refuse derived fuel, incineration, etc. for affecting improved recovery and disposal of waste.
- In order to improve the efficiency of waste collection, especially in narrow roads and slums, transfer stations have to be set up taking in to account local situation. This will not only ensure the proper handling of wastes but also the reduction of transportation costs.
- Developing public-private partnerships leading to the privatization of some aspects of garbage collection, recovery and disposal.
- Improved storage containers for the storage of biodegradable / wet wastes.
- Primary collection of waste stored in various sources of waste generation on a daily basis through active public participation
- Improved collection vehicle design to increase capacity and ergonomic efficiency.
- Promotion of public participation so that volunteers can keep a neighborhood watch on waste management.
- A helpline to tackle various issues such as road sweeping, open dump, open burning, garbage collection, removal of dead animals, clearance of black spots, reporting unauthorised sticking of poster and banners etc.
- Garbage tax should be levied against large and small generators for the disposal of wastes.
- Adoption of GIS with GPS would streamline collection of waste garbage and improves efficiency.
- Constitution of citizen forum in each corporation ward involving local people, NGO's and concerned authorities to ensure close monitoring and supervision of waste management practices regularly.

- Administrative restructuring of the urban local bodies to discharge more efficiently specific responsibilities. This requires a structural changes within the administration aimed at decentralizing authority and responsibilities. This also includes periodic meetings among the staff and between the executives and elected wing of the corporation.
- Adequate training to all the levels of staff engaged in solid waste management to handle respective functional aspects (collection, generation, storage, segregation of waste, etc.).
- Encouraging the involvement of local NGO's in working on various environmental awareness programmes and areas related to waste management including educating the public about the importance and necessity of better waste management.

Conclusions :

Developments in the waste management systems in Bangalore is slow paced nevertheless a sincere one, however it needs upgradation in the areas of processing and disposal. Political and financial hurdles and lack of cooperation by the public in general has created bottlenecks in improving it's efficiency. The potential of community participation, human resource development and legal mandates has to be realised and subsequent changes brought about. Adoption of latest technologies such as MIS-GPS-GIS system have to be taken into consideration while developing a waste management system for Bangalore. The study on IISc campus can be used as a model for the wards in Bangalore. However for any waste management to be successful, the government should step up and take the required initiatives. Even though financial constraints are a part of the system, the government can make a formal and sincere commitment for an integrated SWM approach, fully recognising the advantages of the existing informal recycling network. Waste recycling can be promoted through consumer campaigns that will encourage citizens to co-operate in waste separation and to purchase recycled products. Also, waste authorities should encourage composting and biogasification of wastes, which will reduce the volume of waste to be disposed of. Finally, no SWM can be effective without proper monitoring of its disposal activities. Therefore its effectiveness should be tested on a regular basis.

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