ENERGY

FEASIBLE SOLID WASTE MANAGEMENT

Sathiskumar, R.*
Chanakya, H.N. C+
Ramachandra, T.V.*

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***Energy Research Group**
Centre for Ecological Sciences (CES)
Indian Institute of Science
Bangalore 560 012, India
Tel : 91-080-3600985 / 309 2506
Fax : 91-080-3601428 / 3600085 / 3600683
E Mail : cestvr@ces.iisc.ernet.in
Energy@ces.iisc.ernet.in

+Centre for Application of Science & Technology to Rural Areas (ASTRA)
Indian Institute of Science
Bangalore 560 012, India
Tel: 91-080-309 2447 / 309 2762
Fax: 91-080 - 3600085/3600683
Email : hnc@astra.iisc.ernet.in
Chanakya@astra.iisc.ernet.in
hncbiogas@astra.iisc.ernet.in

SYNOPSIS

Solid Wastes in India pose a formidable challenge to urban managers today and it is roughly estimated that the country produces 30 million tonnes of urban solid waste annually (GOI, 1998). Share of urban population in country's totalpopulation is about 27 percent and per capita waste varies between 0.1 kg and 0.6 kg per day, with an average of 0.33 kg (Bhide, 1990). Prevailing managementstrategies are inefficient, because of its complexity, cost and lack oftechnology, and then ignore solid waste management's socio-economic andecological characteristics. Improper management of these wastes leads to public health hazards, unaesthetic appearance, pollution of soil and watersources such as lakes, groundwater sources, etc. Most parts of India areinefficient in handling wastes in terms of lack of stakeholder participationand inadequate organizational framework. In order to improve the present practice and to avoid environmental degradation, an effort is made in this study to arrive at optimal solid waste management strategy as applicable to developing countries using a prototype model, which represents a typical urban system. With the help of identification of problems and analysis of those problems, optimal management strategies include effective implementationof all essential aspects of urban solidwaste management. Spatial and temporal analyses tools such as Geographic Information System (GIS) and Remote sensing data are of immense help in this regard.

Indian Institute of Science (IISc) campus, Bangalore, India was chosen for developing a feasible solid waste management model. IISc campus represents a cosmopolitan urban set up and the model developed for the campus can be replicated in any urban area in developing countries. Quantification of various wastes from different sectors through field investigations covering collection mechanisms, primary constituents, rates of generation, etc. were carried out. Apart from this, litter generated in vegetated area has been quantified through landuse analysis using field and remote sensing data.

Land cover analyses reveal that about 45% of the total area is under tree vegetation. Stratified random sampling strategy is adopted in order to quantify the litter produced in the campus through regular monitoring of study plots of 1 sq.m spread all over campus.

Based on detailed field observations, strategies for quantification to arrive at the precise quantity of waste generated (attribute information), and effective use of GIS (various layers of spatial information) and optimal management strategy of all kinds of wastes is proposed. The management options are proposed with the help of available guidelines from literature, which were synthesized and modified according to the prevailing conditions. The proposed management strategy could be implemented in urban pockets irrespective of geographical area and population.

INTRODUCTION AND BACKGROUND

From the days of primitive society, humans and animals have used the resources of the earth to support life and to dispose wastes. In those days, the disposal of human and other wastes did not pose significant problems as the population was very small and the area of land available for the assimilation of such wastes was large. However, today, serious consideration is being given everywhere to this burgeoning problem of solid wastes. Rapid population growth and uncontrolled industrial development are seriously degrading the urban and semi-urban environment in many of the world's developing countries, placing enormous strain on natural resources and undermining efficient and sustainable development.

The purpose of the Solid Waste Management (SWM) exercise is to help improvepoor practices of SWM that prevail in many low income countries where this subject has received scant attention compared to other aspects of infrastructure such as water supply and transport. It is a multi-disciplinary field embracingwaste collection, transfer, haulage and disposal and its impact is wide. It is therefore important to take a broad view and not to consider disposal options within the narrow confines of a particular technology. This work isformulated from the available literature and gives particular emphasis to the principle of building on existing capacity of waste managing authorities.

An effort was made to study and suggest improved SWM practice for an area of about 180 hectares (Indian Institute of Science, Bangalore) whose waste generation resembles a typical urban community, equivalent to a ward under city corporation's jurisdiction. The proposed strategies can be replicated in large communities and townships. Optimal SWM strategies for many kinds of wastes are proposed effectively with the help of field investigations and spatial analysis tools (Geographic Information System, GIS), constituting a framework for efficient planning for waste management. Suggestions involving source segregation, designing collection systems, recycling and reuse (usage of organic wastes for production of biogas and fertilizer), optimal routing of collection vehicles, appropriate design of community bins, effective stakeholder participation, hazardous waste management, safe disposal options, etc have been proposed.

SOLID WASTES

Any solid material in the material flow pattern that is rejected by society is called solid waste. Solid wastes arise from human and animal activities that are normally discarded as useless or unwanted. In other words, solid wastes may be defined as the organic and inorganic waste materials produced by various activities of the society and which have lost their value to the first user. 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 of most diverse categories. Wastes that arise from a typical urban society comprises of garbage (Refer Annexure 1 for definitions), rubbish (package materials), construction and demolition wastes, leaf litter, hazardous wastes, etc.

SOLID WASTE MANAGEMENT (SWM)

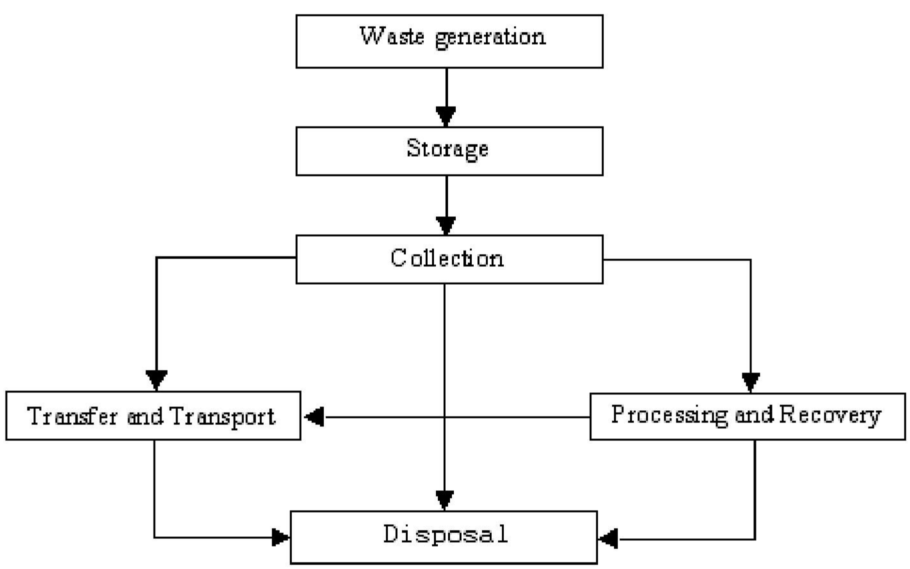
Management of solid waste may be defined as that discipline associated with the control of generation, storage, collection, transfer and transport, processing, and disposal of solid wastes in a manner that is in accord withthe best principles of public health, economics, engineering, conservation, aesthetics, and other environmental considerations. In its scope, solid waste management includes all administrative, financial, legal, planning, and engineering functions involved in the whole spectrum of solutions to problems of solid wastes thrust upon the community by its inhabitants (Tchobanaglous, G. et al, 1997)

FUNCTIONAL ELEMENTS OF WASTE MANAGEMENT

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.



OBJECTIVES OF GOOD MANAGEMENT SYSTEM

The day to day management of solid wastes is a complex and expensive activity. Disposal functions have to be sought for the future, the overall objective being to minimize the adverse environmental effects caused by the indiscriminate disposal of solid wastes. This is of paramount importance to health, environmental protection, natural resources management and sustainable development. Developed countries have adopted sophisticated management practices. Imparting the same in low-income countries is not economically, and technically viable and socially acceptable. However, the management strategies that are to be adopted for low-income countries should ensure maximum safety to the environment.

Management objectives

Management strategies should be in such a way as to perform the following functions

- Protection of environmental health
- Promotion of the quality of environment
- Supporting the efficiency and productivity of the economy
- Generation of employment and income

HAZARDS OF MISMANAGEMENT

Potential hazards of solid wastes are numerous to the living community when it is improperly managed. Solid wastes have the potential to pollute all the vital components of living environment (i.e., air, land and water). Some of the hazards caused by solid wastes are listed below, (Mansoor Ali et al, 1999)

- Environmental pollution from waste leachates and gas evolving from dumped solid waste.
- Air pollution from smoke by burning of waste And Health hazards to the people through inhalation of dust and smoke.
- Health hazards to waste workers and pickers through direct contact with waste.
- Chance of spreading of communicable diseases.
- Unaesthetic appearance
- Poor living environment

CAUSES OF MISMANAGEMENT

Poor management of Solid waste is a bane of urban society. The problem is severe in urban areas because, people from rural area are migrating at an alarming rate for want of employment and better quality of life. Absence of proper municipal amenities adds to the existing menace. Whenever there are sudden surges of population, municipal authorities are forced to take ad-hoc measures, which compound the problem further. The situation should be turnedover for good and it needs an organized and well-thought out approach. In short, the major causes of this dilemma are,

- Burgeoning population
- Industrialization and Urbanisation
- Uncontrolled Economic growth
- Unplanned development activities
- Lack of integrated and holistic approach
- Ignoring importance of socio-economic and ecological aspects

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KEY CONSTRAINTS IN MANAGEMENT

Despite a large body of work on high technology options for waste disposal, there is very little material appropriate for low-income countries. It is observed that inappropriate, expensive and unmanageable disposal systems are being implemented in many places. Numerous technologies / options are available in SWM, among developed countries. Replicating the same in low-income countries is inappropriate / incompatible. The success of waste disposal practices depends largely on overcoming the following constraints,

MUNICIPAL CAPACITY

The scale of task is enormous and regulatory authorities are able to collect only 60-70% of total waste generated (UNCHS 1994), so treatment and disposal inevitably receives less attention. Attempts are being made in a few instances to overcome this lack of capacity by privatizing this operation.

POLITICAL COMMITMENTS

Solid waste management is much more than a technical issues; it has implications for local taxation, employment, and regulation of public and managing authorities. Any change needs political support to be effective. However, it is rarely a priority for political concerns unless there is strong and active public interest. This is viewed as a cost to the "public" without apparent returns.

FINANCE, COST RECOVERY AND RESOURCE CONSTRAINTS

Deployment of a proper management system represents a major investment and it may be difficult to give it priority over other resource demands. Most of the waste management authorities are severely constrained by the lack of resource to finance their services. Since the collection and transport itself usually dominate SWM costs in developing countries, safe disposal invariably receives less attention where as in all other developed countries concentrate on all aspects of management.

TECHNICAL GUIDELINES

Standards of planning and implementation in high-income countries may not be appropriate in low-income countries due to difference in climate, resource, institutions, attitude priorities, etc. However, relatively little appropriate guidance is available for low-income countries. Arising from this uncertainty, officials find themselves ill equipped to plan management strategies, which are both achievable and avoid unacceptable environmental hazards.

INSTITUTIONAL RESPONSIBILITIES

Though managing wastes effectively is the responsibility of the municipality, there is no clearly stated vision of management (i.e. sufficient priority is not given to SWM). Existing vision is accompanied by a typical apathy to solid waste is an "out of sight is out of mind" attitude by the municipalities and public because of strict rule and regulations are not implemented just like as in prevention of emission of water and air pollutants. Waste management necessities the co-ordination of all authorities concerned and may involve departments that are accustomed to acting independently but the lack of accountability in all levels of management. Among the authorities, the roles and responsibilities of different departments need to be clearly defined and accepted by all concerned. Some smaller towns may not have staff with specific responsibility for providing a solid waste management service.

INADEQUATE LEGAL PROVISIONS

In most countries, the laws and regulations on solid waste management are outmoded and fragmented and hence are inadequate to deal effectively with the modern complications of managing wastes in large cities. Most of the laws deal with the general tidiness of the city streets, waste collection and their disposal at places away from settlements. Even these inadequate laws are not fully enforced. This aggravates the situation further.

NATURE OF THE PROBLEM

Solid waste management is a civic problem and it has to evolve optimally and continuously to serve the future generation. Solid wastes if unchecked can not only be a health hazard but will impart multidimensional threats, which include serious detrimental, environmental, social, and economic impacts. Solid waste management in developing countries is a complex issue as the types of wastes generated vary widely because of the varying localities with diverse populations. The boundaries of the analysis of the "waste problem" are difficult to define. A complete and environmentally sound SWM requires effective contribution from all those who are involved in this problem. Everyone is part of the solidwaste generation problem and everyone shall also be part of the solution of proper management i.e., solution depends upon collective human action and efforts.

MAGNITUDE OF THE PROBLEM

The trend of unsustainable patterns of production and consumption is increasing the quantity of the waste and the amount will increase four to fivefold by theyear 2025 (Earth Summit-1992). As many as 5.2 million people, including 4 million children under five years of age, die each year from waste related diseases. The health impacts are particularly severe for urban poor. At present over 2 billion people will be without access to basic sanitation, and an estimated half of the urban population in developing countries is without adequate solid waste disposal services. Solid waste management operations currently absorb 30 to 50 percent of the municipal operating budgets in developing countries (Earth Summit-1992). Some of them have experienced a six-fold increase in solid waste disposal costs over the last decade. The costs are likely to double or treble by early next century. For these reasons, solid waste recycling and reuse has attracted considerable attention worldwide and numerous action plans to promote sustainable human settlement development focussing on environmentally sound management of solid waste have been initiated. Such actions call for an integrated approach to solid waste management.

INDIAN SCENARIO

The importance of proper solid waste management is one of the prime functions of the civic body, as insanitary 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. On the basis of available data, it is estimated that the nine major metropolitan centres in India are presently producing 23,000 tones of solid waste per day. As per recent estimates, Bangalore generates about 3,600 tonnes per day and the following table provides comparative details about garbage generated and cleared in nine major Indian cities (IIED, 1999).

Urban waste situation in some major Indian cities

Major cities	Garbage generated (tonnes per day)	Garbage cleared (tonnes per day)
Mumbai	5800	5000
Kolkata	3500	3150
Chennai	2675	2140
Delhi	3880	2420
Bangalore	**2130**	**1800**
Lucknow	1500	1000
Patna	1000	300
Surat	1250	1000
Ahmedabad	1500	1200

Source: India Today, 31st October, 1994

INDIAN SCENARIO

LACK OF STRATEGIC APPROACH OF FORMAL SECTOR

In most cities, the municipal service for the collection and transportation of urban solid wastes comprises three separate functions as follows,

a)	sweeping, curbside and domestic waste collection from garbage bins
b)	Transportation by handcarts to large or road collection points, which may be open dumps.
c)	Transportation by vehicles to the disposal sites

Indian waste management system is starved of resources to tackle the increasing demands associated with growing urbanisation. Due to budgetary constraints, inadequate equipment and poor planning, house-to-house collection is very rare in India, particularly in certain low-income areas where waste is not collected at all. It is estimated that upto 30-40 percent (UNCHS, 1994) of disposed solid wastes are left uncollected. The areas, which are not serviced, are left with clogged sewers and litter which, create serious health problems for the resident population.

INDIAN SCENARIO

STORAGE

Storage of wastes before final disposal is done at three levels:

At source
Solid wastes are often stored at the source until they are picked up by waste collectors (collection crew) or taken out to be thrown into an open space or a community bin.

At community level
Community bins are used in crowded and narrow market areas, which is a common feature of most developing countries. Because of the high cost of door to door collection many waste management authorities have introduced community bins.

At transfer stations
Transfer stations are established, for economic reasons in cities, which have long haulage distances to final disposal sites. Smaller collection vehicles bring in the wastes collected at their source of generation or from the community bins and larger vehicles transport them away to final disposal sites.Transfer stations are also used as collection and sorting points for recycling materials.

INDIAN SCENARIO

COLLECTION METHODS

Most of the collection systems followed in India are:

Door to door collection
This system is used in narrow streets where a collection truck cannot reach individual houses. The house places the filled containers outside their doors when the waste collectors arrive. Some cities such as Chennai (Madras) and Chandigarh have implemented this in posh localities where influential people reside. On similar lines, Bangalore City Corporation (BCC) recently introduced door to door collection in some wards and management seems to be satisfactory.

Curbside collection
This method is used in wider streets, where the collection trucks can pass through conveniently. The house owners leave the waste containers at the edge of the pavement. The waste collectors collect the waste from the curbside or empty the containers into the vehicle as it passes through the street at a set time and day and return the containers as practiced in Kanpur (UNCHS, 1994).

Block collection

The collection vehicles arrive at a particular place or a set day and time to collect waste from the households. Households bring their waste containers and empty directly into the vehicle (UNCHS, 1994).

Community bins

Community storage bins are placed at convenient locations, where the community members carry their waste and throw it. (These bins are also called Delhi bins, since it was introduced first time in Delhi)

INDIAN SCENARIO

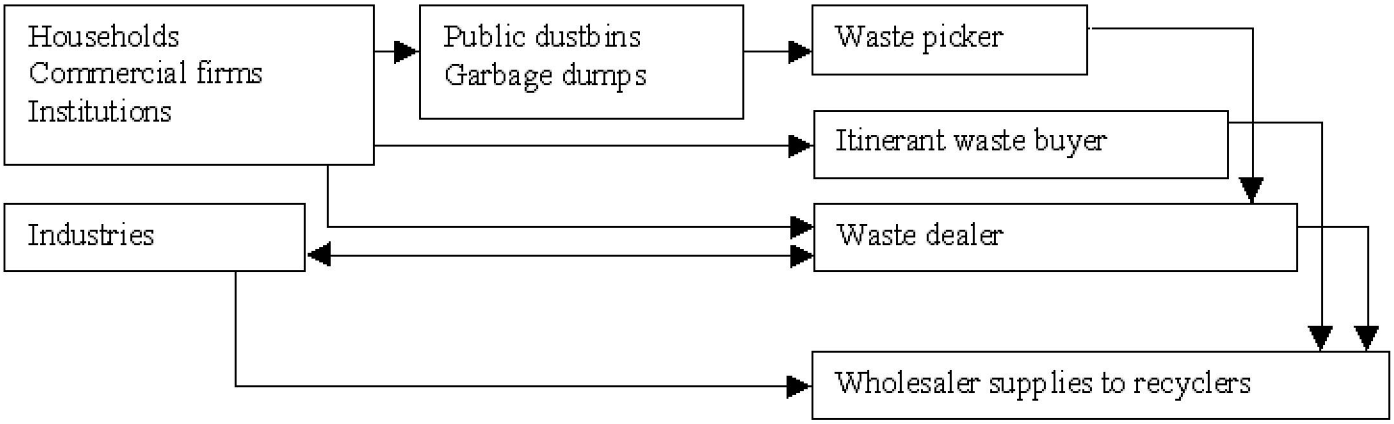
Comparison of Collection Systems

	Collection Methods			
Sustainability Indicators	**Door to Door Collection**	**Curbside Collection**	**Block Collection**	**Community Bins**
Area improvement	√	√	√	X
Convenience of the people	√	X	X	X
Convenience of the staff	X	√	√	√
Handling the extra waste during festival	X	√	√	√
Frequency and Reliability	X	√	X	√

INDIAN SCENARIO

INFORMAL RECYCLING ACTIVITIES

The phenomenon of recycling by means of repair, reprocessing, and reuse of waste materials is a common practice in India. At the household level recycling is very common. Waste is accessible to waste pickers; they segregate it into saleable materials such as paper, plastics, glasses, metal pieces, textile, etc. Rag pickers segregate the wastes directly from the dumps and bins with no precautions and they are exposed directly to harmful wastes. The separated waste is sold to a small waste dealer, from where the waste is transferred to a medium sized dealer or wholesaler. All these activities are not regulated or monitored by any governmental organisation. Due to this informal segregation, volume reduction is achieved, while it ignores social, economic, environmental, and health aspects.



Source: IIED 1999, Informal Waste Management Recovery Process in India

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INDIAN SCENARIO

TREATMENT AND TREATMENT OPTIONS

Waste collected by the formal and informal sectors is delivered mainly to three destinations. The remaining waste goes for disposal. First, high quality materials and used products are cleaned or transformed for reuse. A well-known example is the reuse of old newspapers for packaging material. Second, recyclable materials are traded for recycling purposes. As a result, a wide range of products is generated. Third, organic waste can be converted into compost, which, when used as manure instead of chemical fertilizer contributes to improved fertility of the soil.

Recycling & Reuse

The processes, by which materials otherwise destined for disposal are collected, reprocessed or remanufactured and are reused. Annexure 3 gives the list of commonly separated recyclable components in the municipal waste stream in India. The separation for recycling takes place at households, community bins, open dumps and even in final disposal yards. The recycling business is a complicated chain of operations and varies from place to place. The recycling and reuse (the use of a product more than once in its same form for the same or another purpose) sector of waste management in cities of Asian developing countries is potentially high. Its economic assessment is a difficult task since it is practiced in an informal manner.

Biogas

Biogas contains approximately 60:40 mixture of methane (CH4), and carbon dioxide (CO2) produced by the anaerobic fermentation of cellulose biomass materials - simultaneously generating an enriched sludge fertilizer - with anenergy content of 22.5 MJ/m3, clean gaseous fuel for cooking, for running engines for shaft and electrical power generation with little or no pollution. Many cellulose biomass materials are available in urban and rural solid wastes and may be utilized to produce eco-friendly renewable energy, contributing to the clean waste management. In India, biogas production is currently practiced in many places in rural areas (with cattle dung) and few places in urban areas (with sewage).

INDIAN SCENARIO

DISPOSAL AND DISPOSAL OPTIONS

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 forlonger time and environmental degradation could be high, include mosquito, rodent and fly breeding, air, and water pollution, and degrading of the land.

Sanitary landfilling

Sanitary landfill is a fully engineered disposal option, which avoids harmfuleffects 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. This option is suitable when the land is available at an affordable price. Human and technical resources available are to operate and manage the site.

Composting

Composting is a biological process of decomposition carried out under controlled conditions of ventilation, temperature, moisture 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. Composting is considered when biodegradable waste is available in considerable fraction in the waste stream and there is use or market for compost. Centralised 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.

Incineration

Incineration is the controlled burning of waste in a purpose built facility. The process sterilizes and stabilizes the waste. For most wastes, it will reduce its volume to less than a quarter of the original. Most of the combustible material is converted into carbon dioxide and ash. An extensive sample programmeconducted in India (Bhide and Sundaresan, 1984) reveals that most of the waste had a calorific value of just 3350 joules/g compared with 9200 joules/g in high income countries. Incineration may be used as a disposal option, only when landfilling is not possible and the waste composition is of high combustible (ie 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 and mostly others are either landfilled or dumped. Composition of urban solid waste in Indian cities (% by weight)

City	Paper	Metal	Glass	Textiles	Plastics*	Ash & dust	Organic	Others**
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
Kolkata	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

Source: Planning commission on "Urban Solid waste Management in India", GOI (1995)
*Includes rubber and leather
**Includes bones, stones and woody matter

This data clearly shows that compositions of Indian waste stream collected from garbage bins are mainly of low calorific value with high moisture content. Hence, due to non-combustibility, Indian city waste is not suitable for incineration (Rajababapaiah, 1995).

Main objective of disposal options is to ensure maximum safety to the environment. Imparting processing techniques such as Gasification, Refuse derived fuel (RDF), Pyrolysis etc., require administrative, technical, political, social and economic support.

INDIAN SCENARIO

COMPARISON OF DISPOSAL OPTIONS

	Disposal Options			
Sustainability indicators	**Non Engineered Disposal**	**Sanitary Landfill**	**Composting**	**Incineration***
Volume reduction	X	X	X	√
Expensive	X	√	√	√
Long term maintenance	√	√	X	X
By product recovery	X	√	√	√
Adaptability To all wastes	√	√	X	X
Environmental adverse effect	√	√	X	√

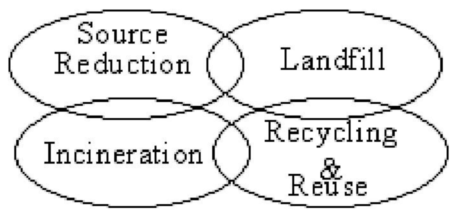
· Incineration with energy recovery

ACTION PLAN

SIGNIFICANCE OF INTEGRATED APPROACH

Management of municipal waste to be effective requires an integrated approach involving components such as source reduction, recycle, reuse, incineration, etc.

The best management practice does not rely on a single processing technique and disposal option, since merit and demerits associated with all prevailing techniques. Final strategy needs to combine various techniques depending upon the constituents in the waste stream. Healthy environment demands an integrated approach that involves complementary use of a variety of practices to handle the solid waste stream safely and effectively with the least adverse impact on human health and the environment. Hence, planning (by various level of government and waste management industry) to be effective has to address the current and future problems faced by the communities and manage municipal solid waste in a safe and efficient way. An integrated approach (EPA, Solid waste dilemma, 1989) for waste management consists of some or all of the following components,



Management practices have to match particular waste stream constituents and select those that are best suited, in order to reduce toxins and quantity and safely extract useful energy or material prior to final disposal.

ACTION PLAN

ENVIRONMENTALLY SOUND MANAGEMENT

Environmentally sound management goes beyond the mere safe disposal or recovery of wastes that are generated and seeks to address the root cause of the problem by attempting to change unsustainable patterns of production and consumption. This implies the application of the integrated life cycle management concept, which presents a unique opportunity to reconcile development with environmental protection. United Nations Centre for Human Settlements (UNCHS, 1994) emphasizes on the following four programme areas, which will vary according to the local socio-economic and physical conditions, rates of waste generation and waste composition.

- Minimizing waste production
- Maximizing environmentally sound reuse and recycling
- Promoting environmentally sound waste disposal and treatment
- Extending waste service coverage

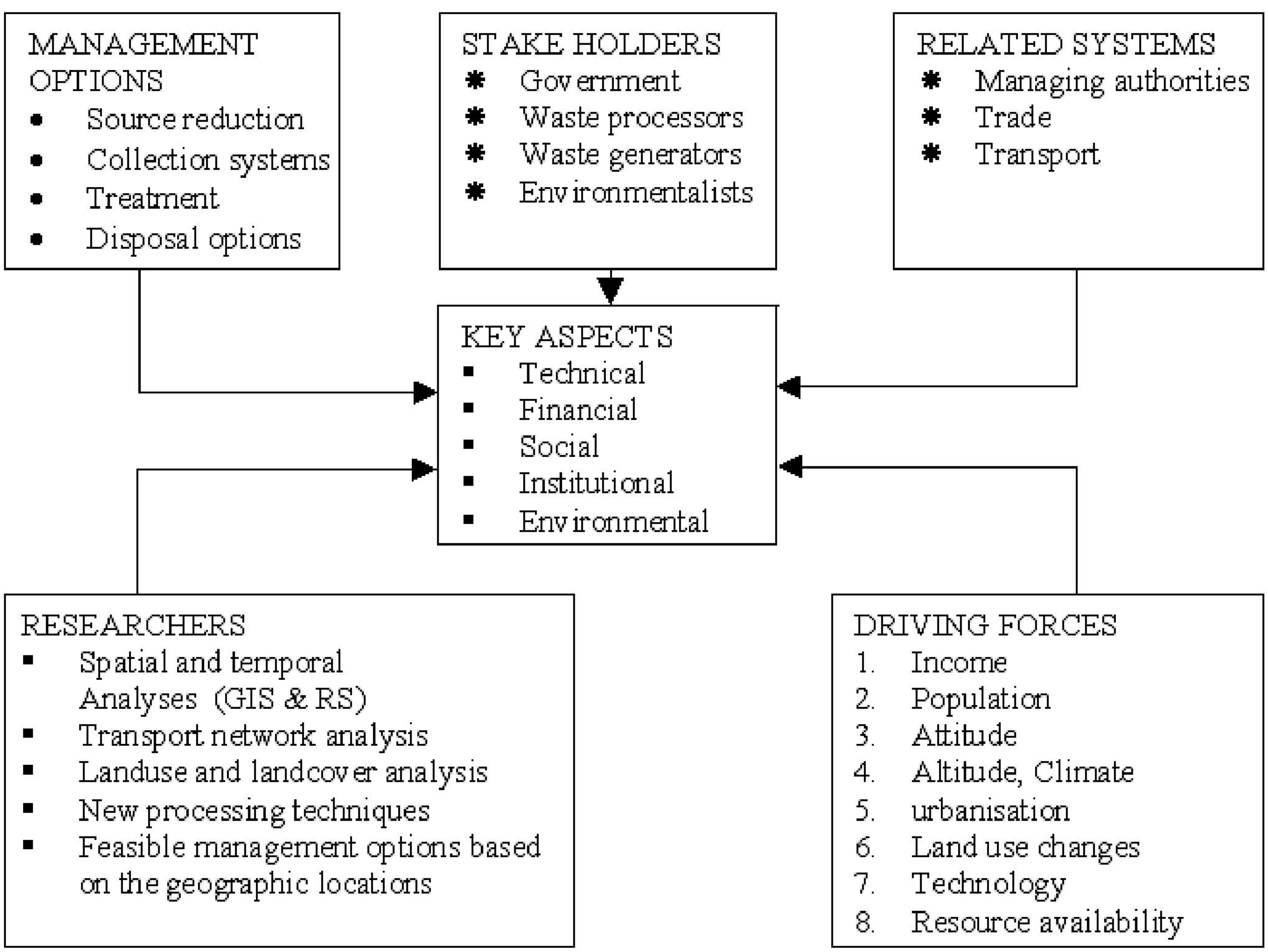
To accomplish these, the management strategies are required to focus on the following:

1. Increase the waste planning and management information (both technical and educational) available to states, local communities, waste handlers, citizens and industry, and increase data collection for research and development.
2. Increase effective planning by waste handlers, local communities and states.
3. Increase recycling by government and by individual and corporate citizens.
4. Increase source reduction activities by the manufacturing industries, government and citizens.
5. Reduce the risk from municipal solid waste combustion in order to protect human health and the environment.
6. Reduce risks from disposal facilities in order to protect human health and the environment.

Fulfilling these aspects helps in overcoming constraints such as, increased waste generation rates and concerns over human health and environment.

ACTION PLAN

FRAME WORK FOR PLANNING, POLICIES AND GOVERNANCE



The overall framework needed for the effective solid waste management is illustrated in the above chart. The integration of all components present takes place at various levels to arrive at feasible management. All components of this framework are intended towards the key aspects of SWM, which are

Technical

Technical aspects include the following issues:

	Regular monitoring of variation in quantity and composition of waste
	Regular review of strategies and rectifying discomforts
	Use and implement effective containers and collection systems
	Use and implement effective component separation techniques
	Improvement in processing techniques
	Studies on cost analysis of recycling activities and minimization of total cost involved in management.

Institutional

Institutional roles and responsibilities concentrate on

	Efficient and proper monitoring of operations
	Management through stakeholder involvement
	Incentives to public participation and efficient workers
	Innovations and whole hearted participation

Financial

The financial aspects are

	Ability to finance the implementation
	Operation and maintenance of the system
	Financing and cost recovery
	Economic sustainability and financial viability of waste management options.

Social

Social aspects include

	No adverse social impact
	Avoiding waste picking creating alternate opportunity
	Ensuring better living condition and sanitation.

Environmental

Environmental issues are

➲	Protecting from negative forms of environmental impact
➲	Avoiding environmental risks
➲	Protecting from long-term environmental hazards

ACTION PLAN

STAKEHOLDERS PARTICIPATION

The critical element is the consultation of common goals and implementation involving all stakeholders. Owning and identifying with the system and its components role is substantial which influence contemporary project design and sustainable management. The common factors that influence non-effective stakeholder participation are as follows,

➲	Lack of commitment of higher levels of government to the waste management
➲	Lack of co-operation with Non Governmental Organisations (NGO) by government and public (Bhuvaneswari Raman, 1991)
➲	Lack of personal interest of concerned local government officials
➲	Lack of Community Based Organisation (CBO) involvement

Collaboration with all stakeholders, especially with waste generating agents is very crucial, implying integration between the formal and informal recycling agents. For example, the segregation of household waste at source would reduce the burden significantly. Stakeholder participation helps in achieving segregation at source and improves the recycling and reuse of wastes. Appropriate incentive helps in effective participation by stakeholders.

ACTION PLAN

PUBLIC EDUCATION

Motivating the public to support the solid waste management program, which includes diverse culture, range of human mentalities and thoughts, requires interpersonal approach. Public education programmes aid in

- Explaining the necessity of public participation
- Raising awareness about waste management needs and concepts
- Advocating adoption of the desired waste management system /attitude.

Policy interventions are possible through active participation of the public. Public education and incentives would help in this regard. Public awareness also helps immensely in lobbying to ensure the government machinery implement the decided management plans.

Several stages of public education are:

AWARENESS: Information about solid waste, health hazards, necessity for feasible management, role of public in management and optimal management strategies. Program planners through variety of methods explain the program in effective manner.

INTEREST: After people have been made aware of waste management issues, they seek more information. Public education helps in answering the queries and provides more information.

TRIAL: Participants and individuals try the programs at this stage and this proves to be very decisive. An adequately staffed and properly trained clearinghouse or hot line is a useful tool to answer questions and provide additional information.

EVALUATION: Participation increases when program requirements are easy to follow. At this stage individuals decide whether to participate or not.For even well promoted programs, initial participation is about 50%. Periodical evaluation and monitoring help in streamlining program requirements and in further improvement.

ADOPTION: Education components in the program usually focus on reinforcing program participation. Ongoing education programs solicit constructive feed back and provide new program information when necessary. Public support and participation would continue to grow for well thought out and implemented programs. This helps in adoption of management practices.

MAINTENANCE AND ADAPTATION: Incentives and education while keeping participation rates high also help in maintaining the system thereby ensuring long term sustainability. Users adapt the system to their convenience.

ACTION PLAN

PUBLIC INVOLVEMENT

The effective waste management is a continuing process of public education, involvement, implementation and evaluation. Among these, key issue is wholehearted public participation, which has to face several interwoven components:

PEOPLES' CONCERNS: People concerns about waste management which include costs, aesthetics, odour, littering, social issues of handling etc. have to be put on the public agenda, which fascinates the public involvement there by effecting the management methods.

INVOLVEMENT: Representatives of various interest groups (regulatory officials, individuals from neighboring communities, local waste management experts, stakeholders, representatives from environmental and business groups)are to be encouraged to participate. Bringing representatives of interest groups together and providing a forum for communication is an important need for long-term sustainability of the program.

ISSUE RESOLUTION: Interest groups make their points of agreement and disagreement clear to each other and to program planners. The various groups then attempt to understand and resolve points of conflict, which is the most important issue for the sustainability of practice adopted.

ALTERNATIVES: Participants make a list of available alternatives, including taking no action. At this stage participants may use the different criteria to analyse comparative economics, environmental impacts, and other aspects of each alternative which helps in arriving at a most viable alternative.

CHOICE: At this stage, the decision-making body decides all alternative /or a group of alternatives to implement in a participatory manner. The decision-makers are required to communicate the reasons behind their choice by explaining the necessary trade offs and the anticipated impact of the chosen alternative or alternatives on the communities.

RISK ANALYSES: Economic and environmental consequences of each alternative are discussed in such a manner, the public understands the results of choosing one alternative over another to avoid future annoying of public.

IMPLEMENTATION STRATEGY: While implementing the suggested or agreed alternative, the steps necessary to carry out the program are described and potential adverse impacts are mitigated, if possible, which helps in coordinating the public and beginning of the programme successfully.

EVALUATION AND MONITORING: The managing authorities continually evaluate the model and solicit input from affected groups. Ongoing evaluation and monitoring helps provide an information base for making future waste management decisions and understanding the system health.

SPATIAL ANALYSES TOOLS

APPLICATION TO ENVIRONMENTAL PROBLEMS

Spatial and temporal analyses tools such as Geographic Information System (GIS) and Remote Sensing data (Satellite information) are playing a pivotal role in management of natural resources, urban planning, etc. since last two decades.

GIS play fundamental role in the application of spatial data to any environmental modeling with or with out remote sensing data. The integration of spatial data and corresponding attribute data which refer to qualities or characteristics of places with spatial and location information (data base management systems) with the help of computers have revolutionized environmental modeling. These developments have played a prominent role in rapid and reliable analysis of spatial data.

- Use of Geoinformatics in planning the alignments of linear features like road, railways and canal etc. have become quite popular on account of many commercial GIS and CAD software available in the market.
- Organizations like Survey of India, where the Digital Cartographic Data Base (DCDB) is already available in 1:250,000 scale, are using the Digital Elevation Model (DEM) for generating road and railway alignments and alternative route plans.
- Geoinformatics and related GIS technologies are already being activated for sustainable environment planning, hazard predictions, monitoring and planning of related mitigation programmes like predicting land slides, earth quakes, cyclones, natural resource management, water quality monitoring, routing and transportation applications etc.

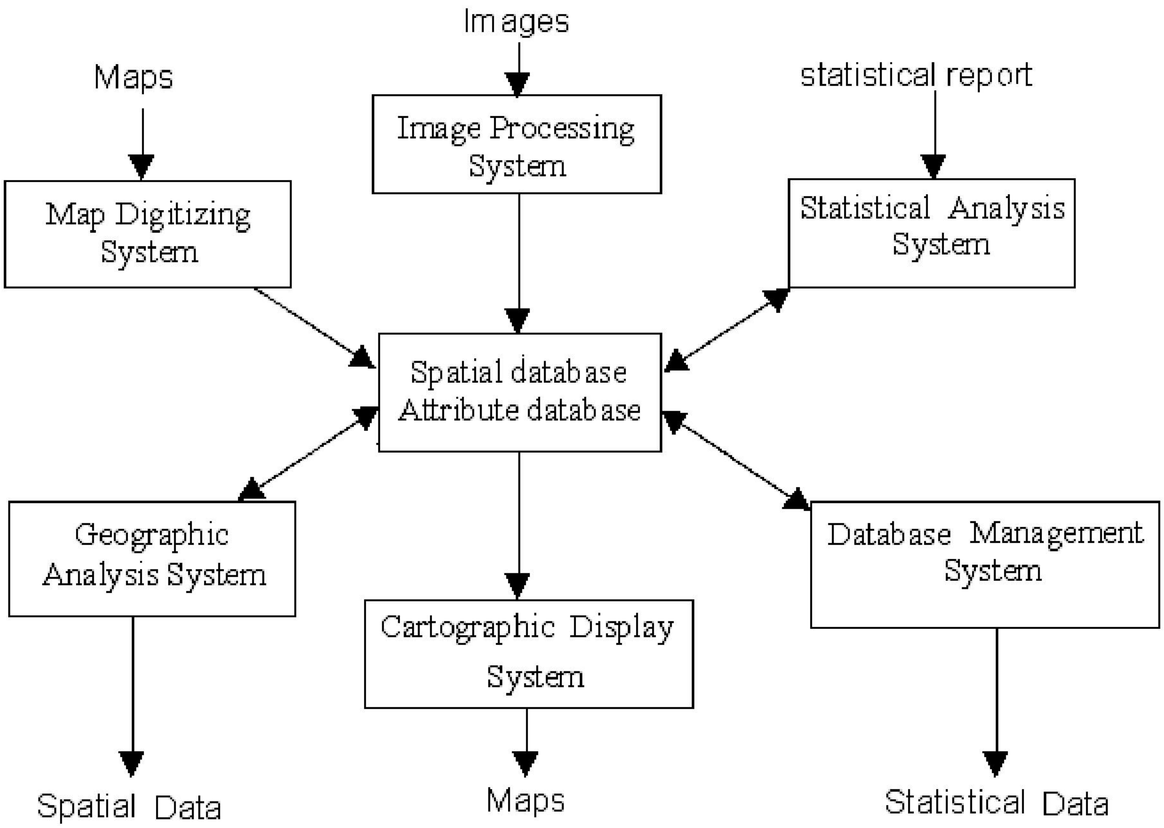
SPATIAL ANALYSES TOOLS

GIS-INTRODUCTION

Geographical information system (GIS) is a systematic integration of computer hardware, software and spatial data, for capturing, storing, displaying, updating, manipulating and analyzing in order to solve complex management problems. GIS is used as a tool, which aids in analyzing the data obtained with reference to their geographic location (Strafaci, 1999). GIS aids as decision support system with spatial maps and attribute databases. GIS integrates maps with reports, graphs and photographs to present results into powerful tools for decision-makers.

SPATIAL ANALYSES TOOLS

GIS-COMPONENTS



Cartographic display system

- This system allows users to select and extract a particular database or map output on the screen or printer etc.

Map digitizing system

- This system enables users to convert existing paper maps to digital form, thus further aids in developing database.

Database management system

- This system has the ability to analyse the attribute data. Term "attribute" refer to qualities or characteristics of places with spatial and location information.
- Software, which provides cartographic display, map digitizing and database query capabilities, are often referred to as automated mapping facilities management (amfm) systems (Ronald Eastman, 1997)

Geographic analysis system

- This component has the ability to analyse the truly spatial characteristics. Term "spatial" refers to any two or three-dimensional data whether or not it relates directly to the surface of the earth.

Image processing system

- It helps to analyse and classify the remotely sensed images (digital images) according to various classification techniques, which could be interpreted with the help of training data.

Statistical analysis system

- This helps in statistical analysis of spatial and temporal data which is required in scenario analyses.

SPATIAL ANALYSES TOOLS

GIS - KEY TASKS

Import data
Probably the most time intensive step in setting up a GIS is obtaining spatial and attribute data sets in a consistent format and scale. Spatial maps used till now in paper format (by many agencies) are converted to geo-referenced digital format through scanning, digitization and geo referencing techniques. This can be updated with the latest information through satellite information.Attribute data may be entered manually or may be imported from preexisting sources.

Database Management
GIS is essentially a spatial map linked to attribute database. It manages theunderlying spatial and attribute data in a Relational Database Management System (RDBMS). Relational databases store various layers of information in tables and are linked together by common fields.

Querying and Data Analysis
Performing queries is the most useful and powerful analytical capabilities of a GIS.

Visualisation of Data
Visualisation is one of the vital capabilities of GIS, helps to display results of query and in creation of high impact visuals, which are easy to interpret.

BEST STRATEGIES BY NESTING ESSENTIAL ASPECTS, FRAME WORK AND GIS

VIABLE STRATEGIES

Strategic approaches for SWM is integration of available data, guidelines and framework and elimination of the constraints. Main objective of SWM is to arrive at a proper storage with least negative environmental impact, efficient collection system, engineered processing and disposal (according to constituents present in the waste stream). Analysis of spatial data i.e., landuse and land cover pattern, transport network, collection network etc., along with informationrelated to quantity and quality of wastes (through GIS) enable the authorities involved in the solid waste management to come out with feasible options.

POSSIBLE SOLUTIONS

Arriving at viable strategies and wise decisions enables the authorities to handle the waste effectively and remove discomforts to public. Utilization of available technology and expert involvement in the management could fulfill the aspirations of public and authorities. The data available on waste generation, sources, local conditions for collection system and capacity of managing authorities help in designing a proper management system, thus eliminating problems related to storage, collection, and disposal.

REVIEW OF LITERATURE

Literature pertaining to the present research, namely a waste-management system and technique, has been compiled from various sources such as CES (Centre for Ecological Sciences) library, web browsing related to GIS and environmental modeling, etc. There is a lot of literature pertaining to thisarea of waste management in general. However, only the most relevant literaturehas been cited.

Rajabapaiah (March, 1995) proposed free cooking gas production from IISc garbage, estimated to have fermentable matter 1080kg (88%), combustible matter 60kg (5%) brickbat 50 kg (5%) and recyclable matter 26 kg (2%). This quantification was based on the data compiled at disposal site. Suggestions include ASTRA's biomass plug-flow fermentor technology for the effective utilization of fermentable organic matter to produce biogas and bio fertilizer.

The merits and demerits of various disposal options of solid waste for developing countries and a framework for selection of disposal option with a case study of Karachi is given in Down to Earth (Mansoor Ali, et al. 1999)

The United Nations Center for Human Settlements (UNCHS-HABITAT, 1994) report discusses methodology for the promotion of solid waste recycling and reuse in the developing countries of Asia. Various techniques of separation of recyclable material, significance of recycling, recycling processes and materials, key issues and constraints of management policies are also listed.

In 1989, Environmental Protection Agency, USA, prepared an agenda for action for solid waste dilemma, discussing about the hierarchy of integrated management,goals, responsibilities and planning of municipalities. The emphasis is on increasing available information, source reduction activities, and recycling and reducing risks of combustion & landfills.

Mansoor Ali et all (2000), provided the success and sustainability indicators to assess primary collection schemes through a case study in Khulna, Bangladesh. This is based on perspectives of users, municipalities, non-governmental organisations, community based organisations, small contractors and sweepers. The indicators used for evaluation are area improvement, convenience, affordability, frequency, reliability, sustainability, recognition, increased income, etc.

EPA-US Decision - maker's guide to solid waste Management (1995), explains the importance of public education and involvement, design approaches of collection and transfer, source reduction and recycling activities, composting, combustion and land disposal.

Portland Metro solid waste department, USA, (1996) has developed a decision support tool for management with help of GIS. Case studies include analyzing participation rates at household hazardous waste facilities, assisting haulers with routing collection vehicles, evaluating service levels of yard debris programs, developing travel time models for transfer stations, inventorying ofmultifamily complexes and recycling levels, calculating recycling participation rates, distributing compost bins and evaluating etc.

CASE STUDY

Indian Institute of Science Campus

STUDY AREA

IISc (Indian Institute of Science) campus is chosen for developing a feasible SWM strategy. The campus limits are enclosed within 13.010550 to 13.020830 latitude and 77.559440 to 77.573880 longitude. The area falls in the 57G/12 of Survey of India (SOI) toposheets of scale 1:50000, 57/G of scale 1:250,000.

IISc is located in the northern part of Bangalore City having lush vegetation and campus has green canopy of trees covering the buildings. The campus, consisting of five bounds, covers an area of 180 hectares. The main campus covers around 150 hectares. The elevation at IISc campus varies from 914 m to 942 m (from mean sea level). The natural terrain of the campus is rolling and provides good natural drainage. Eastern part of the campus forms the major portion of the catchment area of Sankey Lake located to the Southeast of the campus (Fig 1). A large drain running all along the eastern side of the campus forms the main feeder to the Sankey Lake. Fig 2 provides the boundary of IISc with geo co-ordinates while Fig 3 maps the buildings and Fig 4 refers to road network.

This study explores the present waste handling practices within the IISc campus with various interdisciplinary activities (40 departments, 400 faculty members, 800 supporting staff, 1500 students and 450 residential quarters) representing a typical urban community. The institute has all kinds of wastes arising from various sources like residential, commercial, educational, open area and vegetative area.

CASE STUDY

NATURE OF WASTES

The nature of the waste generated within the campus comprises of,

- Domestic wastes (food leftovers, vegetable peels, plastic, house sweepings, clothes, ash, etc.)
- Waste arising from educational, administrative and commercial buildings (paper, plastics, glasses, etc.)
- Hazardous wastes arising from laboratories, health Centre (Radioactive chemicals, hazardous chemicals, infectious wastes, etc.)
- Waste arising from road cleansing (leafy matters, dust, construction & demolition wastes, etc.)
- Waste from vegetated area (litter, garden trimmings, tree cuttings, mowing etc.)

CASE STUDY

PRESENT SCENARIO OF SOLID WASTE MANAGEMENT IN THE CAMPUS

Generation

Campus residents and visitors involved in academic, administrative and commercial activities produce considerable quantity of wastes. Generation of wastes varies with season, academic and social activities and time. During the festivals, seminars, etc the generation rate is considerably high.

The campus has 45% of vegetative cover through out the year (Murari, 1999) and litter production is quite high. Litter production varies with season and type of tree species. Quantification of litter entailed a detailed field survey along with land cover and land use analyses.

Storage

Waste bins of various types are distributed all over the campus in different locations to ensure the waste is not dumped on the roadside. Different types of waste bins namely cylindrical concrete bins (CON), small wooden bins (SB), cubic concrete bins (CUB), masonry hut bins (HUT) and stone bins (STB) are in use. Hut bins are constructed at key locations where quantity of waste expected is quite high. Daily collection at hut bins constitutes about 20% of total solid waste in the campus. Figure 5 depicts the location and distribution of bins. Small bins are provided to collect frequently generated wastes such as cigarette covers, envelopes etc. and are placed at strategic locations. Concrete bins, stone bins and cubic bins are provided at places, where waste is expected regularly. In spite of all these, wastes are openly dumped on the ground at various locations for varying periods of time (Fig. 5).

Collection

Campus solid waste management is handled by the Estate Office. Initially, collection was done by workers employed by estate office with the help of one tractor and a pick-up mini-truck. Total crew size is six members and two drivers (to operate in two shifts). Four loads of waste were taken and the daily crew operated in two shifts (morning two and afternoon two). Recently (November 2000) the collection was entrusted to Bangalore Development Authority (BDA) recognized waste collection agents. Two truckloads are taken out daily and the crew size is 8 workers and 2 drivers. The frequency of collection from each bin is now 1 to 3 days (i.e., all bins are cleared once in 1 to 3 days). Collected wastes are dumped and burnt at common dumping site about 12 kms away from IISc. With this approach, while the institute environment is kept reasonably clean but valuable resource (70% of which is fermentable organic waste) with a significant plant nutrient load is being lost. This could have been converted to wealth through appropriate technologies available at campus.

Mostly community bin collection mechanism has been employed. The domestic waste is collected with all other wastes arising from other activities, which increases weight of waste to be transferred. In some localities such as duplex, E-Type, D-Type and Tunga residential staff quarters (Fig 3), door to door collection has been attempted recently. Collection charge per household per month is Rs.15. Regular street sweeping and roadside garden trimmings are done and wastes are dumped in bins and sometimes in drainage also.

Transferring

Transferring the waste from dustbins to vehicles is done manually with the use of spades, rakes and similar equipment and transferred to the collection vehicle. Inadequate precautions are taken while handling harmful wastes such as glass, biological wastes etc. The route followed currently is the one convenient to 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. Till November 2000, collected waste was transferred to dump yard (located in North-eastern side the campus). These dumped piles were frequently burnt. Today, by entrusting the responsibility to BDA recognised contractors, waste is transferred to BDA's dumping yard near Madivala, Bangalore. Wastes dumped in dump yard were frequently burnt which caused both health hazards from toxic fumes and organic resource loss. This necessitates the wise use of organic wastes and environment-friendly disposal options. Damage to the ecosystem and the immediate environment has to be accorded the highest priority in deciding this options.

Disposal
Both in the past and in the present, inadequate attention has been paid to engineered disposal and its practice. Waste is simply dumped on the ground, open to the atmosphere as followed elsewhere without appropriate treatment and resource recovery practice.

Waste picking
Waste is accessible to waste pickers, who segregate re-saleable matter (paper, plastics, glasses, metal pieces etc.). Rag pickers segregate the wastes directly from the dustbins without any protective gloves and are exposed directly to harmful wastes. Due to this informal segregation, some volume reduction is achieved. However, such segregation disturbs the aesthetics of the collection system as wastes are littered all around the place.
Food wastes (food leftovers, vegetable peels, etc.) from various messes, used as animal feed are collected by agents regularly. Fresh surplus food is transferred to schools.

Source segregation
An attempt was made to segregate paper and plastics in the academic area by providing separate bins in all rooms in selected departments [Centre for Electronic Design and Technology (CEDT) and Centre for Ecological Sciences (CES)] for inmates to dispose plastic and paper in separate dustbins. From small dustbins in each room, wastes are then transferred to big containers located at common place, so that the contractor appointed by the institute can collect the waste. Segregation at individual level has been working reasonably well while at next stage (transferring to big container and then collection by a contractor), the practice has come to an end, due to lack of monitored collecting mechanism at IISc.

Hazardous wastes
Wastes that cause potential hazards to humanbeings and animals are referred to as hazardous wastes. Generally hazardous wastes can be classified into three categories namely, radioactive wastes, biological wastes and hazardous chemicals. At IISc, radioactive chemicals are used by various departments generally as radiotracers. Radioactive substances like Tritium, Phosphorus (32P), Sulphur (35S), carbon (14C), Iodine (125I), etc are used. The Institute has designed an innovative method to dispose radioactive wastes in an environmentally sound way in concrete silos with least or no harmful effect on eco-system. On the last Thursday of every month, wastes collected from individual departments are put into appropriately labeled containers and sealed and placed at radioactive waste disposal site. These are ensiled according to conventional practices of handling low-level radioactive wastes.

Very few departments at IISc use hazardous chemicals. Hazardous chemicals such as solvents, carcinogenic chemicals, etc are used in about five departments. Used chemicals from various laboratories are given varying levels of importance with respect to disposal practices and they are often mixed with general liquid wastes. Hazardous chemicals such as solvents, carcinogenic chemicals, etc. rejected from various laboratories are given inadequate importance and they are often mixed with general liquid wastes. A few workplaces however use fume hoods to dispose of mildly carcinogenic solvents. Acids and alkalis are typically dispersed by dilution with water. Mutagenic substances used are few and used in very small quantities. However, sometimes they are disposed along with bottles, packing material and mixed with general solid waste stream.

Pathogenic hospital wastes (1-4kg/week) (COMIND-SWM, 1999) and animal bedding material are disposed by a common incinerator.

Litter
Litter is usually the dried parts of plants fallen on the ground. The litter largely contains leaves, flowers, fruits, seeds and twigs. Litter can be a non-timber plant products (NTPP) too - an economically important waste and could be converted to wealth with proper management (currently collected litter is transported out of campus and is burnt, thus the valuable wealth is lost). This resource if managed properly would return valuable nutrient to the soil. However, burning bioresource in dump yard leads to air pollution and affects surrounding inhabitants.

The IISc campus is covered with good vegetative canopy throughout the year. The litter produced and litter collected by collection vehicle is about one truckload /day containing dry and green leaf litter. The case study explores the following important issues,

➲	to obtain an estimate of litter production or availability
➲	to help understand the nutrient cycling and its importance
➲	aid computation of woody litter available for fuel, etc.

CASE STUDY

OBJECTIVES

- To Integrate spatial analysis tools to arrive at the best SWM strategy
- To suggest optimal solid waste management system within the campus

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CASE STUDY

METHODOLOGY

This study proposes to arrive at optimal management strategies of solid waste in the campus. The key parameters required to perform this study are:

- Identification and quantification of sources (dust bins) and major constituents in the waste
- Estimating total weight, type and volume of waste per day and their variations
- Spatial data such as road network, location of buildings, etc.
- Litter production, location and season-wise data
- Finding apt location, volume and design of bins
- Finding optimal route for collection vehicle

Identification and quantification of sources (dust bins) & major constituents in the waste
Estimating total weight and Volume of waste per day
Building spatial data
Estimating total quantity of litter produced from vegetation
Finding optimal route for collection vehicle
Finding apt location, volume and design of bins

CASE STUDY

METHODOLOGY

Identification and quantification of sources (dust bins) and major constituents in the waste

An exploratory field investigation involving 7 days monitoring was carried out to find out the type and number of dustbins. Numbers were assigned to all dustbins for reference and the enumeration was done on the dustbin itself.

Waste constituents: In order to arrive at the major constituents that are present in each bin, regular monitoring was done which include visual estimation of approximate quantity and major constituents of dustbins. This enabled in understanding bins constituents and their dynamics (regularly cleared and filled bins). Table 1 lists - number of bins, spatial distribution and types of dustbins. This exercise was repeated thrice in order to understand the variation in composition. It was observed that the major constituents fell into four major categories: paper and paper products, plastic and plastic products, leafy matter and domestic wastes (Annexure-2).

CASE STUDY

METHODOLOGY

Estimating Total weight and Volume of Waste per day

In order to quantify wastes collected at each bin, both visual (volume estimation) and weighing experiments were carried out. In the visual experiment, daily variation of volume of dustbin and approximate percentage of constituents at the surface were noted. This was done initially for seven days covering all types of bins spread over the campus. Since the quantum of wastes collected at green bins was very less, further investigations were carried out for 15 days covering 123 bins (excluding green bins). This exercise was repeated thrice in order to take in to account daily, weekly and seasonal variations. Visual volumes observed per bin are later converted in to equivalent weights taking in to consideration the density of materials (which depend on composition of wastes - paper, plastic, etc.).

In order to verify the reliability of visual experiments (to quantify wastes), mass of constituent solid wastes were computed by actual weighing (using a weighing balance of 100kg with sensitivity of 0.5 kg). This monitoring was carried out in selected 25 sample bins for 5 consecutive days. These sample bins spread all over the campus represent all areas covering diverse activities. Sample bins were selected taking in to account the constituents and frequency of wastes generated in bins. There were differences in the weights computed through visual and weighing experiments in sample bins. Hence, these experiments were repeated and bins were monitored continuously for another 15 days to arrive at a significant level of consistency.

In sample bins, both visual and weighing experiments were carried out. This enabled in arriving at the relationship among the variables (for each constituent) got from visual and weighing experiments. Based on correlation coefficient and % standard error, the best relationship was chosen. This relationship was used to quantify the wastes of all bins in the campus (bins monitored visually, by considering volume of wastes).

CASE STUDY

METHODOLOGY

Building spatial data

Integrating spatial information along with corresponding attribute information is a vital part of this study and helps in arriving at feasible management. Geographical Information System (GIS) software Mapinfo5.5 was used to create various vector layers from the Survey of India (SOI) toposheets of scale 1:1000. Digitized vector layers include

- Boundary

- Road network
- Buildings distribution (built up area)
- Distribution of all bins - spatial map of active bins
- Open dumping sites
- Land use and land cover map based on field data and remote sensing data
- Map showing litter study plots (used to quantify litter production)
- The spatial information of base layers (boundary, road network, distribution of buildings and dustbins - Figures 2, 3 & 4 are generated using SOI maps of scale 1:1000 and field data collection. The vector layers of boundary, road network, buildings and dustbins were overlaid for further analyses.
- Computing NDVI (Fig 8) with IRS 1C multi-spectral data for land cover analyses.
- Land use analysis is done by mapping of trees, buildings, etc. with the help of Global Positioning System (GPS). Vegetation analyses were carried out by dividing the campus in to one-hectare grids. Various vegetation indices [such as species density, tree density, diversity indices (Shannon-Wiener and Simpson's) and Evenness index*] were calculated for each grid (Murari, 1999). Details about these indices are listed in Annexure-3.
- Overlaying these vegetative indices layers with equal weightage per layer, divides the campus in to 15 distinct zones. These zones correspond to the present land use pattern (Fig 12).
- Distribution of bins in each zone and present collection routes was mapped (Fig 14).
- By using zone map and corresponding attribute data related to bins (such as total quantity and type of solid waste generated per day), a thematic map (Fig 15) was created to get an overall idea of zones and its contribution in the total solid wastes generated at IISc campus.
- With these spatial and attribute database the feasibility options of solid waste management and aspects of recycling were explored.

CASE STUDY

METHODOLOGY

Estimating Total Quantity of Litter produced from vegetation

Usual practice to estimate litter quantity is through litter traps covering an area at least 10 percent of the total area (Shailaja and Sudha 1997).Due to time constraint in the present investigation, litter trap method is not effective and practical. Hence, a new approach through stratified random sampling was adopted to estimate the litter quantity for entire campus. Sample plots of 1 sq.m. were chosen randomly (stratified random sampling) covering all vegetative area. These plots were monitored for litter quantification every day for seven days. The average value is computed for each study plot, which is extrapolated to the entire IISc campus based on tree and species density and results are given in Table 5. The leaf litter quantification was done also taking into account moisture content and woody branches.

CASE STUDY

METHODOLOGY

Finding Optimal Route for Collection Vehicle

Efficient routing and rerouting of solid waste collection vehicles can decrease costs by reducing the labor expended for the collection. Routing procedures usually consist of two separate components: micro routing and macro routing (EPA, 1995).

Macro routing, also referred to as route balancing, consists of dividing the total collection area into routes sized so they represent one day's collection for one crew. The size of each route depends on the quantity of waste collected per stop, distance between stops, loading time, and traffic conditions.

Micro routing can define the specific route that the collection vehicle should follow. The method selected for micro routing must be simple enough to use for route balancing, when system changes occur or to respond to seasonal variations in waste generation rates.

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, animal problems and late transferring to biogas plant. Optimal routing (Fig 17) 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 in each zone is left as it is, considering experience of collection workers.

CASE STUDY

METHODOLOGY

Finding Apt Location, volume and Design of Bins

In order to improve the existing collection system, it is necessary to rectify the problems associated with bins, which spoil the present management. All the bins in the campus are not handy for rapid and clean collection. Many of the concrete bins are broken, turned over and improperly used. Number of bins for a location is not uniform. Further, 2-4 bins are scattered in several places at a single location because a single bin is not adequate. The volumes of existing bins are sometime insufficient and there is a need to arrive at volume that suits to all locations and all kind of wastes.

There is a need to replace or modify present bins. This can be done with the knowledge of waste type, quantity and its variation with time. For this purpose average generation of waste and clearance frequency is computed (bin-wise) for all bins and is listed in Table 8. This helps in designing appropriate volume at each location.

At present, among all the bins, concrete, cubic, and stone bins are open to atmosphere. Due to lack of regular clearance, constraints associated with these bins are odour, nuisance due to animals and unaesthetic appearance. They need to be modified to help in rapid collection system taking into account factors such as durability, compatibility, easy handling and reuse.

CASE STUDY

RESULTS

- Extensive field investigations were made to identify all the sources (dust bins). **Table 1** shows the types of bins and their spatial distribution. Zone 1 & 2 which include academic, hostel and residential buildings have higher number of concrete bins.
- **Table 2** shows the densities of the various constituents, based on field measurements. This helped in converting the volume of constituents (visual experiment) to their corresponding mass.
- Four cycles of visual estimates and two cycles of weighing experiments enabled approximate prediction of weight and volume produced in the campus.
- **Table 3** shows the results of four cycles of visually determined estimates. In the first cycle, all small green bins were considered as a result of which there was a wide variation in total quantity when compared to subsequent estimates. All subsequent estimates were carried out without considering green bins.
- **Table 4** lists the results of weighing and visual estimates carried out for 25 bins for 15 continuous days. Relationship between weights calculated for visual volume and actual weight is arrived through regression analyses.

The probable relationships are as follows,

PAPER Actual =0.2682*(weight by visual estimate)+0.393 DOMESTIC WASTES Actual weight = 0.1649*(weight by visual estimate)+2.354 PLASTICS Actual weight = 0.7347*(weight by visual estimate) LEAFY MATTER Actual =0.3924*(weight by visual estimate)

These best-fit relationships helped in quantifying wastes generated in bins, which were monitored only visually.

- The results obtained from the first three cycles of experiments show considerable variation between visual and weighing experiments. These experiments were repeated taking in to account drawbacks of earlier exercise. Consistency was achieved in the fourth cycle. Fourth cycle coincided with the new academic year.
- Fourth cycle experiment results are listed in **Table 5** This helped in arriving at average total weight produced per day and weight of each component. It is about 940 kg per day, produced in the campus of which 681kg is fermentable matter (leafy matter and domestic waste), and remaining is paper and plastic products.
- **Table 6** shows Zones 2 and 7 (hostel and residential quarters) which contribute the major proportion of fermentable matter. Zones 1 and 3 (administrative and academic buildings) have higher share of recyclable products such as plastic and paper products. This zone wise quantification explores the feasible options of implementation of recycling aspects and criteria for collection mechanism.
- Litter quantification with the new approach, explores available bio-resource in the form of litter and the results are shown in **Table 7**. For entire area total quantity of dry leaf litter expected is around 2.74 tonnes per day.
- **Table 8** shows Average rate of generation/day in all types of bins (Concrete, Stone bins and Cubic bins). This provides an idea for suitable volume needed for bins to avoid spillage. The average weight of waste and volume expected in these bins are 22 kg and 0.4 m3.

CASE STUDY

Table 1 Distribution of dustbins and types of bins

ZONE NO	CON	SB	HUT	CUB	STB	OD	OTHER	TOTAL
1	25	22	1	1	1	1		50
2	28	19	5	1	3	5		61
3	11	19	3	1			1	35
4	11	8	1	1				21
5	10	2				1		13
6	2	0						2
7	2	2	2	1				7
8	27							27
9	0							0
10	0							0

11	0							0
12	8	17			1		1	27
13	4	0						4
14	4	1						5
15	4	4						8
	141	95	12	5	5	7	2	267

CASE STUDY

Table 2 Densities of major constituents obtained from field investigation

S No	Constituents	Density kg/m3
1	Paper	50
2	Plastics	20
3	Leafy Matter	140
4	Domestic Waste	330

CASE STUDY

Table 3 Results of Visual estimates of Solid wastes

(observation recorded for 123 large bins)

SL No	Parameter Period	I cycle from 17/6 to23/6	II cycle from 28/6 to12/7	III cycle from 27/7 to 10/8	IV cycle from 4/9 to 19/9
1	Total volume (m3/d)	39	31	21	27
2	Total weight(kg/d)	4900	3240	2220	3030
3	Weight /bin (kg/d)	19	24	17	23.8
4	Paper (kg/d)	1400	1147	582	556
5	Plastic (kg/d)	620	598	398	136
6	Leaf (kg/d)	405	240	320	761

7	Domestic waste (kg/d)	2475	1255	920	1577

CASE STUDY

Table 4 Quantification of wastes by weighing.

SL No	Parameters Period	I cycle from 8/8 to12/8	II cycle from 9/9 to23/9
1	Total weight(kg/day)	433	595
2	Paper (kg/day)	197	190
3	Plastics (kg/day)	36	25
4	Leaf (kg/day)	73	240
5	Domestic wastes (kg/day)	91	130
6	Others (kg/day)	36	20
7	Weight in kg /bin /day	3.3	4.25

CASE STUDY

Table 4 Quantification of wastes by weighing.

Correlating weights obtained by visual experiment and direct weighing experiments,

Sl No	Constituents period	weighing (25bins) II cycle from 9/9 to23/9	Visual(25bins) II cycle from 9/9 to23/9	For iv cycle using regression Analysis(123bins)
1	Paper (kg/day)	33	103	170
2	Plastic (kg/day)	5.5	6	89
3	Leaf (kg/day)	40	100	317
4	Domestic wastes (kg/day)	22.4	89.9	364

Total weight obtained during the experiment period = 940 kg/day

CASE STUDY

Table 6 Zonewise quantity of different wastes generated per day.

Ave.weight generated in kg/day							
Zone no	**Open dump**	**active bins**	**paper**	**plastics**	**leaf**	**dom.waste**	**Total.weight**
1	1	23	47.46	20.25	31.48	9.67	108.86
2	5	31	35.28	20.67	108.88	120.54	285.39
3	0	14	31.46	10.64	18.20	26.78	87.10
4	0	11	18.80	7.42	7.15	7.27	40.39
5	1	0	0	0	0	0	0
6	0	4	3.09	2.14	9.39	18.40	33.03
7	2	22	17.28	18.63	105.56	141.14	282.12
8	1	0	0	0	0	0	0
9	1	0	0	0	0	0	0
10	0	0	0	0	0	0	0
11	0	4	6.53	3.10	18.83	2.77	31.24
12	0	1	0.87	0.50	1.29	3.11	5.79
13	0	5	4.01	3.00	9.72	18.41	35.15
14	0	4	1.32	0.79	1.60	5.69	9.41
15	0	4	3.49	2.17	5.30	12.64	21.60
	11	123	169.63	89.34	317.43	364.48	940.11

CASE STUDY

Table 7 Results of Litter quantification based on tree density.

Density Category	No of Trees per ha	no of Grids of size(1ha)	Ave.litter quantity in gm/ m2/day	Total quantity category wise in kg/year
1	362 to 622	12	5.35	234330.00

2	252 to 362	13	3.57	169396.50
3	176 to 252	28	6.91	706202.00
4	134 to 176	31	2.97	336055.53
5	102 to 134	29	3.57	377884.56
6	78 to 102	30	11.14	1219830.45
7	46 to 78	29	5.39	570531.59
8	1 to 46	8	10.71	312732.24
		180		3696262kg/year

Total quantity of litter produced for the total area = 3696.26 t/year
Total quantity of litter produced after removing moisture = 1178 t/day
Total quantity of litter produced after removing woody litter = 1001 t/year
Total quantity produced per day per 180ha = 2.74 t/day in the campus
Total quantity produced per hectare per day =15.24 kg/ha/day or 5.546 t/ha/Yr

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CASE STUDY

Table 8 Rate of generation/day in all Concrete, Stone and Cubic bins.

Bin	**Existing**	**Volume in m3**			**Weight in kg**		
Type	**Volume in m3**	**Max**	**Min**	**Ave**	**Max**	**Min**	**Ave**
Concrete	0.4	0.8	0	0.176	33.66	2.35	7.19
Cubic	0.4	0.8	0	0.172	33.66	2.35	7.28
Stone	0.6	0.67	0	0.197	22.90	2.39	7.31

Maximum volume, the bin should have =2 times the average volume
=2* 0 .2 m3 = 0.4 m3
Maximum weight to be handled =3*ave.weight = 3*7.5kg =22.5kg

CASE STUDY

Spatial information output results

The base layers of IISc campus for the analysis were generated from the scanned maps of survey of India 1:1000 sheets. **Figure 1** shows the location of IISc with surrounding lakes. The 'boundary' layer of IISc campus having four bounds is shown in **Figure 2**. IISc campus covers an area of 180 hectares, of which the main campus occupies about 158 hectares. The road and buildings layers generated are shown in **Figure 3** and **Figure 4** respectively. The road network depicts paved, unpaved, overhead bridge and subways. Buildings are classified based on usage as administrative, academic, residential, and buildings of dining facilities. The layer (**Figure 5** & **Figure 6**) with buildings, road network and dustbins show the spatial distribution of dustbins. **Figure 7** shows tree distribution at IISc campus and **Figure 8** depicts canopy cover at IISc (NDVI).**Figure 9** tree density (trees per hectare) while **Figure 10** Species Density (species per hectare). **Figure 11** shows species diversity per hectare (Shannon-Wiernor index). **Figure 12** shows zones of IISc campus based on landuse pattern with spatial spread of buildings. **Figure 13** zones of IISc campus with distributions of buildings and active waste bins where the experiments were carried out and open dumps. **Figure 14** shows locations where collection vehicles collect the waste (present collection system). **Figure 15** thematic map with all zones and proportion of waste generated. **Figure 16** map of litter study plots sprawling over campus. the plots were located in the map using Global Positioning System (GPS). **Figure 17** illustrates optimal route forwaste collection vehicle

CASE STUDY

DISCUSSION & CONCLUSIONS

- The field investigations and analysis reveals that the average waste per day is (Average of 15days) about 940 kg and % contribution of each constituents are shown below

Sno	Contents	Kg/day	%
1	Paper & products	169.63	18
2	Plastics & products	89.34	9.5
3	Leaf litter	317.43	33.7
4	Domestic wastes	364.48	38.8
	Total	**940.11**	**100**

This above table clearly indicates that the fermentable portion (c.73%) is biodegradable and needs to be consigned for biogas fermentation in an environmentally sound scenario.

- Analysis of results shows that zones 1,2 and 3, which include academic, administrative and hostel buildings contribute considerable quantity of recyclable materials like paper, paper envelopes, and plastics (polyethylene 90%) which have good market value when properly segregated from the waste stream. Separate dustbins needs to be provided to separate recyclable materials at the source itself in these zones, thereby source reduction and also recycling may be accomplished.

- While considering zones 2 and 7 where fermentable matter quantity (80% of total waste) is quite high, these need to be recycled /used to produce compost and biogas. As these zones comprise residential quarters, hostels and mess, the door to door collection would be effective to segregate organic wastes. Door to door segregated waste collection, which is already in practice in some part of the residential area, needs to be extended to other areas. ASTRA's biomass plug-flow fermenter technology (biogas plant) is a viable alternative to utilize the available domestic waste and biomass.

  This system should handle 800 kg of garbage per day, and has potential payback period of 3 years. In addition produces enriched manure after digestion. The generated biogas could be supplied to those low-income households (such as helpers, who use fuelwood and kerosene). This arrangement would reduce the pressure on bioresource available at the campus apart from dependence on non- renewable fuel - Kerosene. The committee be constituted consisting of users and other stakeholders and entrusted the responsibilities of day to day maintenance and other financial aspects (collection of nominal fees from biogas and slurry users) to ensure sustainability in operation and management of the system.

- This zoning and zonewise quantification explores the feasible options in

  - Designing collection system in terms of knowing the preference of the zone according to the waste characteristics and quantity.

- Awareness provided on segregation /re-use options to the waste generators
- Implementing of recycling and reuse activities
- Waste minimizing operation
- Selecting disposal option.

- In the current practice of collection, the vehicle collects wastes generated in the campus at a frequency varying from 1 to 3 days. It is necessary to arrive at better collection strategies for better utilization of waste materials generated at IISc campus as well as the collection system. In this regard, a transfer station is proposed to handle the waste collected from the other zones before final disposal. This station enhances further separation of bio-resources and recycling products and reduces the volume of waste going to final disposal.
- The next issue is with regards to hazardous wastes (hazardous chemicals, radioactive wastes and wastes of biological origin).
  - The radioactive wastes are generally used by a few departments in radiotracer type of work and carry low levels of radioactivity. The present practice of handling and storage is satisfactory and is designed along specifications laid out by BARC. The available space will meet the needs for the next decade at current rate of waste generation.
  - Hazardous chemicals are used by a few departments and bulk of it consists of various forms of solvents. Safety norms for these vary widely. They are handled differently at various workplaces. Bulk solvents receive greater safety attention compared to compare to harmful solvents/chemicals used in smaller quantities (e.g. solvents are disposed in fume cupboards in one department). In general there is a need to create an overall awareness in handling, storage and disposal based on newer findings of potential hazardous arising from use of these chemicals.
  - Wastes of biological origin arise from two sources, medical facility at the IISc and bedding material from animal experiments. Current disposal by incineration needs to be improved / upgraded to meet future standards of both pollution board and biological safety.
- As per the present practice, which prevails in developed and developing countries for the final disposal facilities such as incineration, sanitary landfill, gasification etc. have their own disadvantages and advantages and if final disposal relies only on one disposal method, it won't be environmentally safe. Though different disposal techniques are available, it is unfortunate that nowhere in India, the fully engineered disposal of solid wastes is implemented due to lack of strict laws. The current practice of waste disposal is a non-engineered one and campus waste is mixed with Bangalore City solid wastes, dumped (open dumping on ground) in corporation disposal site which is burnt (thus valuable wealth is exported and lost). Major constituents of campus waste being biological and organic in nature, it should be recycled or converted to valuable energy and manure.
- An effective monitoring mechanism needs to be evolved (such as COMIND sub committee on SWM). This system needs to include technical expertise with stakeholder concerns in all aspects (hazardous wastes, general wastes, landuse, etc). It should regularly monitor the waste management activities and carry out timely studies to predict the changes in waste generation and resource utilization. Thus, vital and timely suggestions can be made to waste management authorities in collection, recycling and reuse issues. To enhance the public

involvement and public education to avoid open dumping and to make them aware of source reduction and source segregation, regular end-user participation programs needs to be conducted.

- The proposed integrated approach (i.e., combination of aspects like source reduction, recycling & reuse, incineration and landfilling) allows only inert materials to final disposal, which cause almost no environmental degradation.

8 REFERENCES

1. Bhide, A.D. 1990. Regional Overview on Solid Waste Management in South East Asia Region. World Health Organisation, New Delhi.

2. Bhide A.D. and Sundaresan, B.B, 1984. Street Cleansing and Waste Storage and Collection in India, Managing Solid Waste in Developing Countries, Holmes J.R.(ed).

3. Bhuvaneswari Raman, 1994. An investigation of non-govermental organisations, community based organisations and private incentives in indian cities, workshop on "Linkages in Urban Solid Waste Management", Bangalore: R-44

4. COMIND-sub committee, 1999. Action Plan -Solid waste management, IISc, Bangalore.

5. P. Rajabapaiah, Waste management for IISc, 1995. Centre for the application of Science and Technology to Rural Area, IISc, Bangalore.

6. Earth summit, 1992. The united nations conferene on Environment and development, Rio de Janeiro, Brazil: 184-188

7. Environmental Management in Developing Countries, 1995, Waste Management Vol II, Institute for Scientific Co-operation,Tubingen: 92

8. GOI- Government of India. 1998. "Launching a Clean City Compaign in the States in the 50th year of independence." Brochure published by the Ministry of Urban Affairs and Employment (Department of urban Development) in Quarterly journal of the All India Institute of Local Self-Governance, Vol. LXIX, no. 2, April- June : 96-105

9. http://www.esri.com/library/userconf/proc95/to050/p018.html

10. International Institute for Environment and Development (IIED). 1999. Analyzing Urban Solid Waste in Developing countries: A Perspective on Bangalore , India, working paper no 24, CREED Publications, Amsterdam, Netherlands:9-12

11. International Institute for Environment and Development (IIED). 1999. Analyzing Urban Solid Waste in Developing countries: Integrated Modelling of solid waste in India, working paper no 26, CREED Publications, Amsterdam, Netherlands: 1-6

12. Mansoor Ali, Andrew Cotton and Ken Westlake, 1999. Solid Waste Disposal for Low-Income countries, Loughborough University, London : 8

13. Mansoor Ali, Jenny Appleton and Andrew Cotton, 2000. Success and sustainability Indicators - a tool assess primary collection schemes, Loughborough, London: 5

14. Raja Raja Varma Murari, 1999. Optimal Design of Rainwater Harvesting Structure using spatial and Temporal tools, PG thesis, Government College of Technology, Coimbatore: 38-39

15. Strafaci, A.M., 1999, Geographic Information Systems: An Introduction to the technology, Essential hydraulics and hydrology, Haestad Press, USA.

16. Shailaja Ravindranath and Sudha Premanth, 1997. Biomass studies (field methods for monitoring biomass), Oxford & JBH Publishers, New Delhi: 102-104

17. Tchobanaglous,G. Theisen,H. and Eliassen,R. 1997. Solid wastes: Engineering Principles and Management Issues, McGraw-Hill publications, NewYork, USA: 52

18. Ronald Eastman, J 1997. IDRISI for windows-users guide, Clark University, USA: 2-1, 2-7.

19. United Nations Centre for Human settlements (UNCHS), 1994. Promotion of Solid Waste Recycling and Reuse in the Developing Countries of Asia, Kenya:1.1

20. US Environmental Protection Agency, 1989. The Solid Waste Dilemma: An Agenda for action,Washington:17

21. US Environmental Protection Agency, 1995. Decision Maker's Guide to Solid Waste Management, Vol II, Washington : 4-31

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Annexure 1

Definition of terms

Ecology: The total study of living beings or organisms and effect on the surroundings. Also the interaction or dependency between organisms and their setting and effects on each other.

Ecosystems: A specific and self contained area in which all species, plants and animal interact with each other and are interdependent upon each other as well as the environment in which they live.

Environment: Natural environment includes water, air, and land the interrelationship that exists among and between water, air land human beings other living organisms, and property.

Environmentalists: Activists who work to preserve the environment from further deterioration.

Garbage: It contains putresible organic material and will decompose rapidly, especially in warm weather. It needs special consideration due to its nature of attracting vermin and of producing very strong odour.

Infectious wastes: Any substance or material which has come into contact with or has been used with a substance where an infectious agent may have been present.

Refuse-derived fuel(RDF)

Product of a mixed waste processing system in which certain recyclable and non-combustible material are removed, with the remaining combustible material converted for use as a fuel to create energy.

Annexure 2

Paper and paper products

Newsprint
Photocopying paper
Computer stationery
Writing paper including exam papers and duplicating paper
Plastic and metal coated cartons
Packaging paper and paper cartons

Plastics and plastic products

LDPE, HDPE
Polycarbonate
PET
Styrofoam
PVC and Chlorinated plastics
Plastic coated Packaging paper, metallized films (biscuit covers)
Computer related spares

Domestic wastes

Food and allied wastes
Animal bedding materials
House sweepings
Straw and similar decomposable materials

Leaf matter

Garden cutting, pruning, mowing and similar wastes
Fresh and dried leaf litter

Others

Glass, metal, cottons, sacks, clothes, etc.

Annexure 3

Glass	-broken and unbroken bottles, windowpanes
Metals	-ferrous and non ferrous components
Plastics	-plastics sheet, piping, and plastic bags
Paper/cardboard	-newspapers, and packaging cardboard
Textiles	-clothing, and tapestries
Woods	-broken furniture and garden waste
Rubber/leathers	-old tires, and shoes
Organic wastes	-kitchen waste, and garden waste
Demolition debris	-wood, steel and rubble
Waste oils/greases	-engine oil and waste grease
Bones	-food leftovers and slaughter house wastes

Annexure 4

Simpson's Indices

Gives the dominance and diversity of species.

C=S(ni/n) 2

ni= Number of individual in each species
N= Total number of individuals in that community
C= Dominance index
Reciprocal of dominance index is diversity index

***Shannon-wiener Index**

This method is used to compare diversity between different community and habitats. The value of Shannon-Wiener index usually falls between 1.5 and 3.5 and rarely surpass 4.5.

H=-S(Pi loge(Pi))

Where Pi=(ni/N)
H = Shannon wiener diversity index

***Evenness Index**

This index shows the equality of abundance.

e= (H/logeS)

e = Peiben evenness index
S= number of species

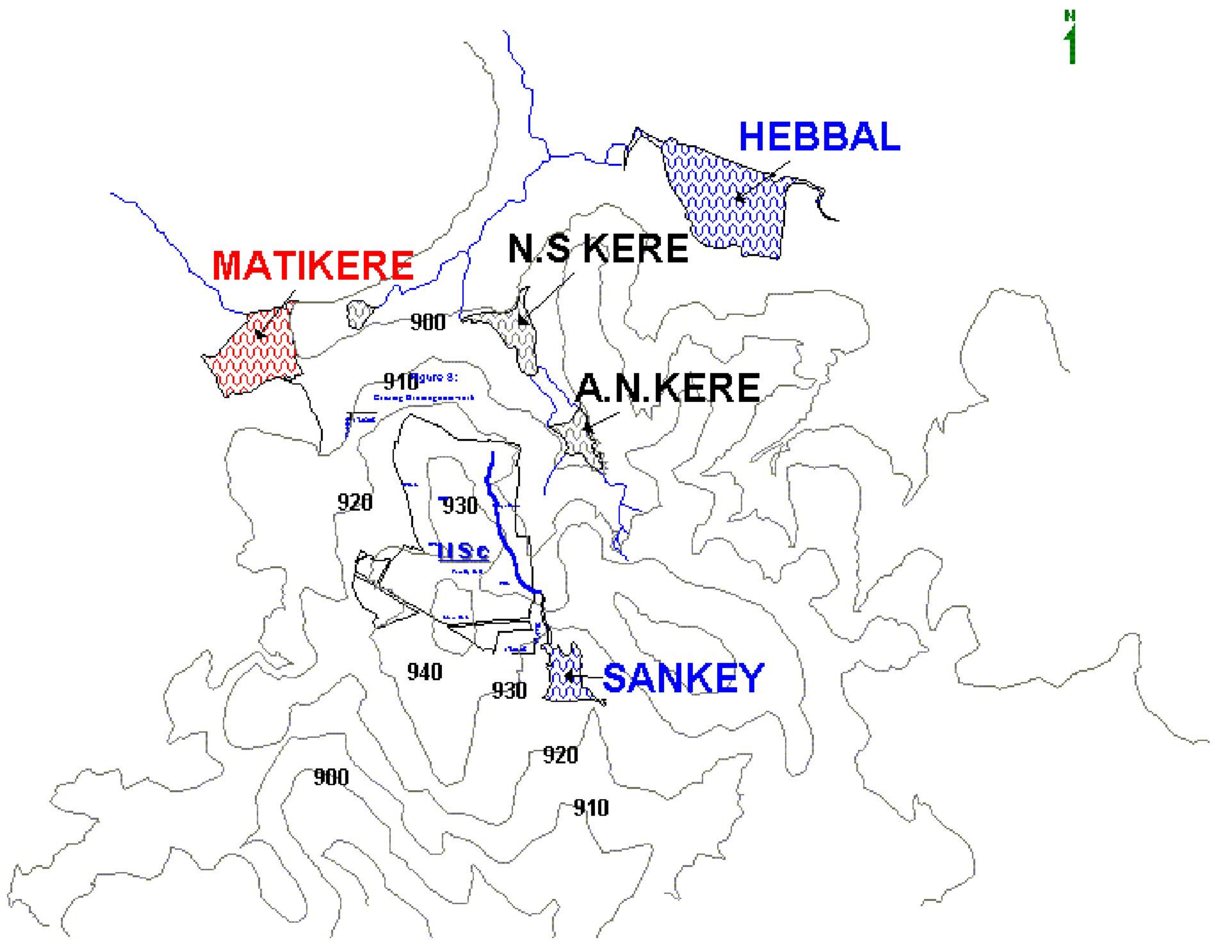
NDVI (Normal Difference Vegetation Index)

It is a vegetation index that separates green vegetation from the background soil brightness by using satellite data.

NDVI=(NIR-RED)/NIR+RED

The value lies between -1 to 1 [0 and negative values indicate no vegetation].

Fig 1: Location of IISc with surrounding lakes



Existing Lakes

Lakes converted into residential layouts

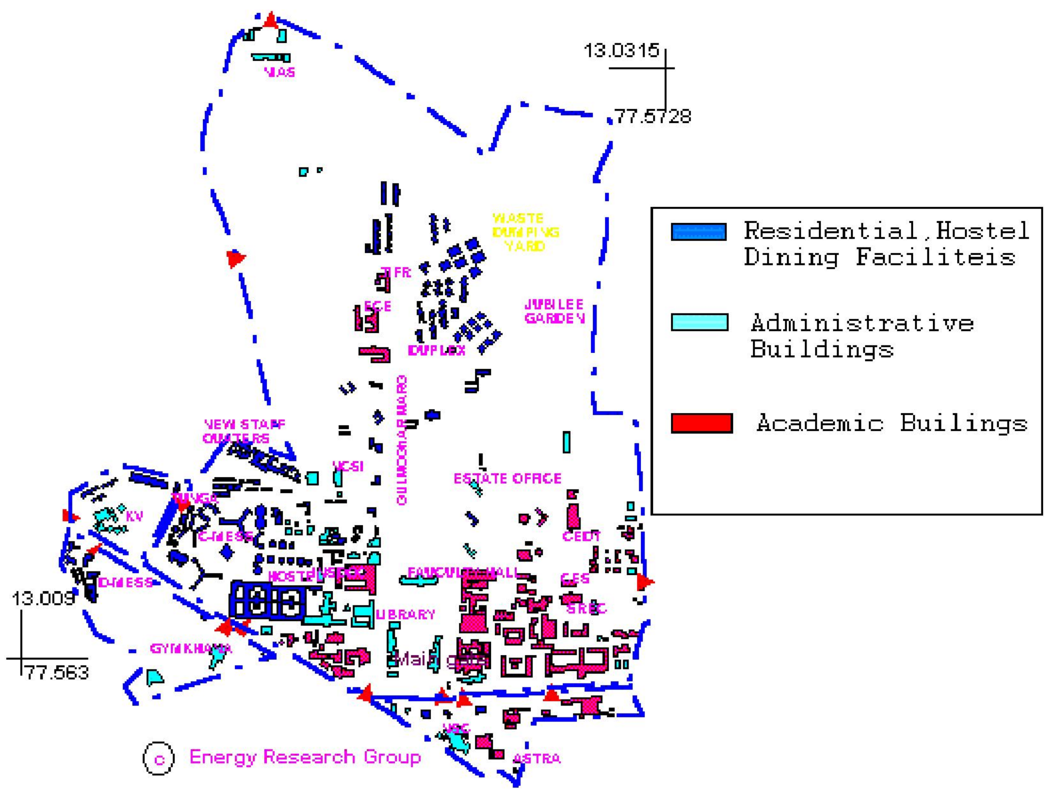
Non-existant Lakes

N.S Kere - Nagashetti Halli Kere

A.N Kere - AshwatNarayan Kere

Figure 2: The Boundary Layer of IISc Campus with Four Bounds

Figure 3: Shows IISc Buildings Distribution



Figur 4: Shows the Roadnetwork

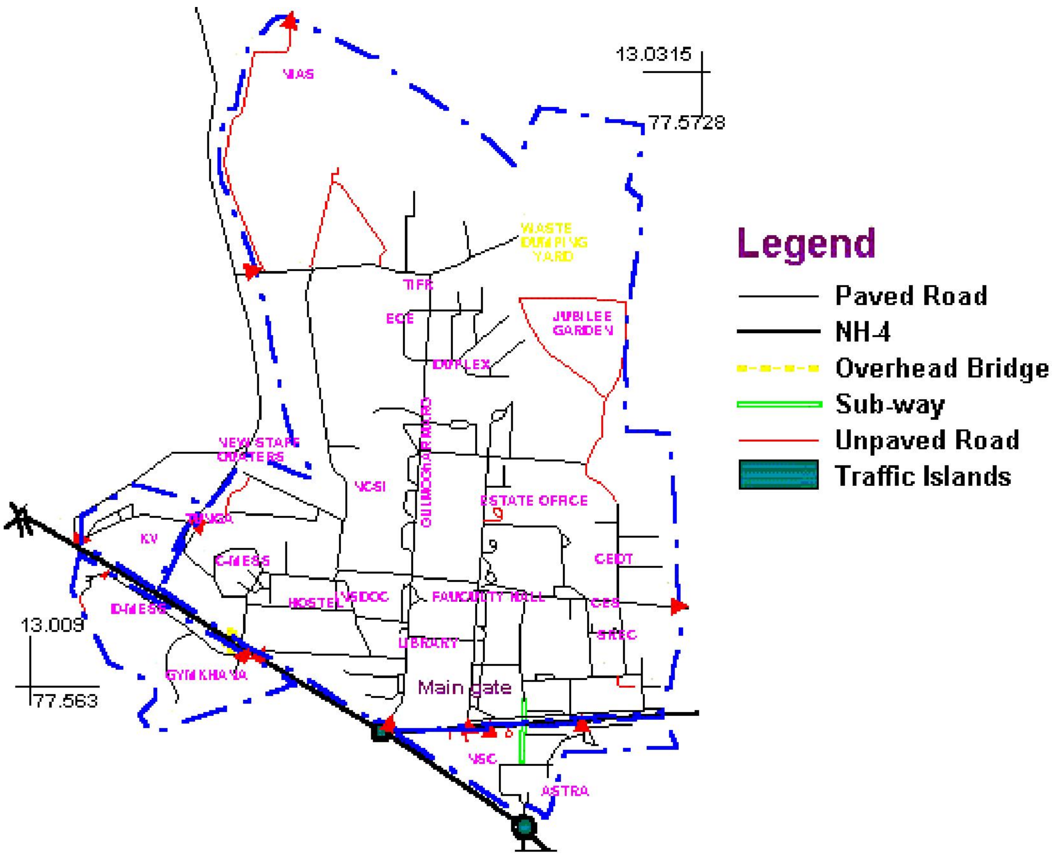


Figure 5: Buildings and Spatial Distribution of Dustbins

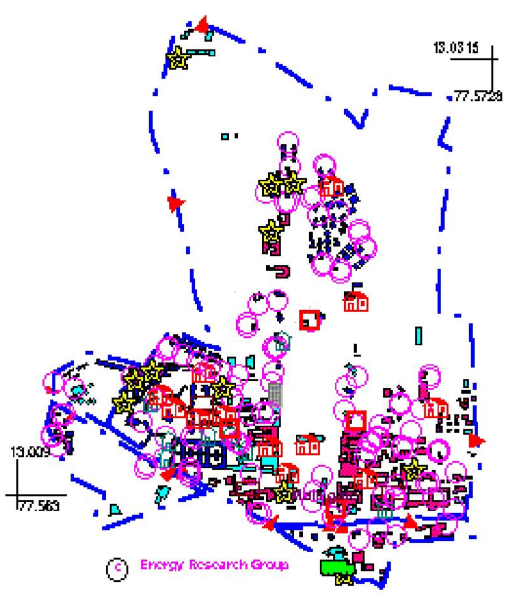


Figure 6: Overlaying of Figure 4 and 5

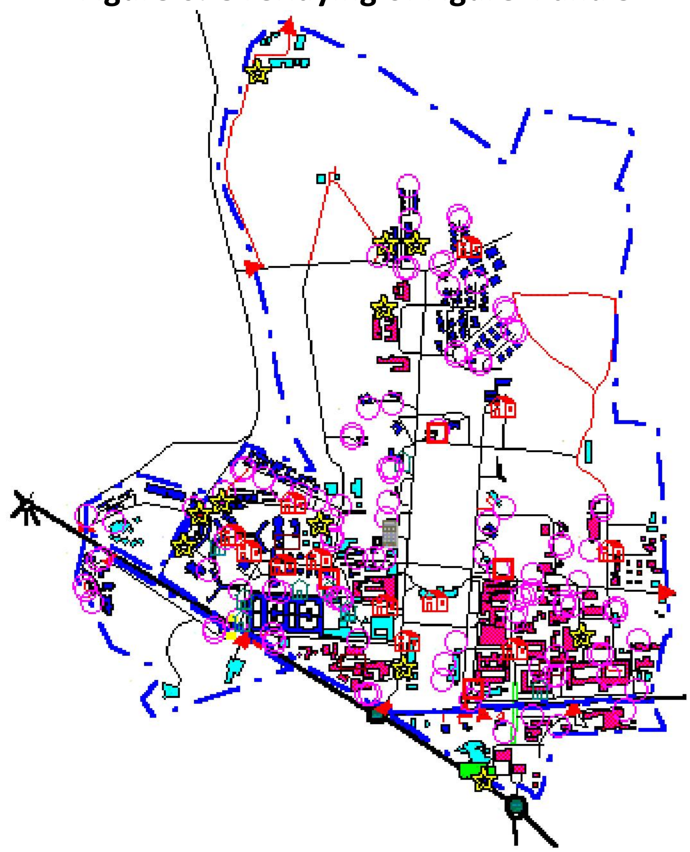


Fig 7: Tree distribution at IISc Campus

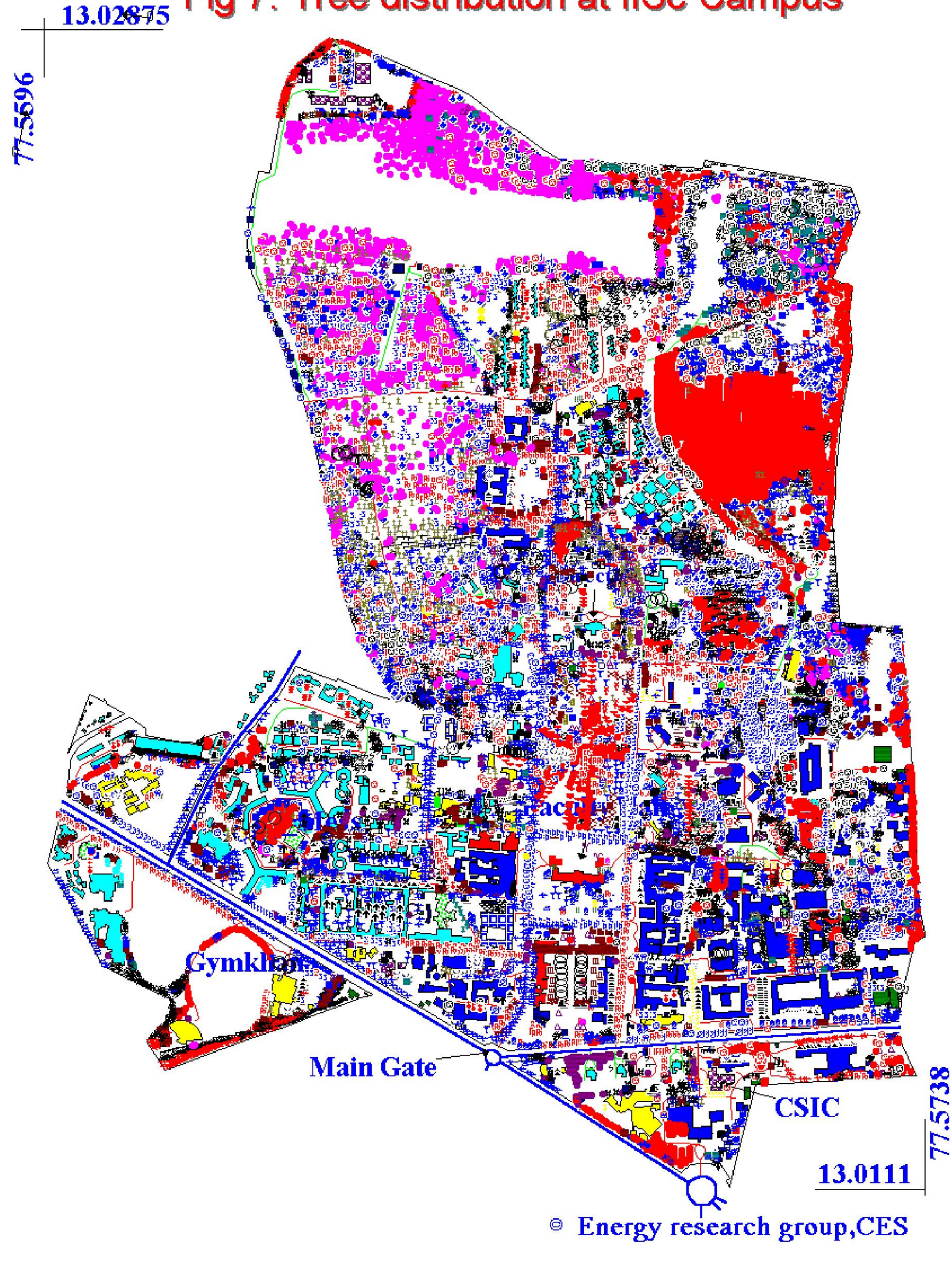


Figure 8: Canopy Cover at IISc (NDVI)

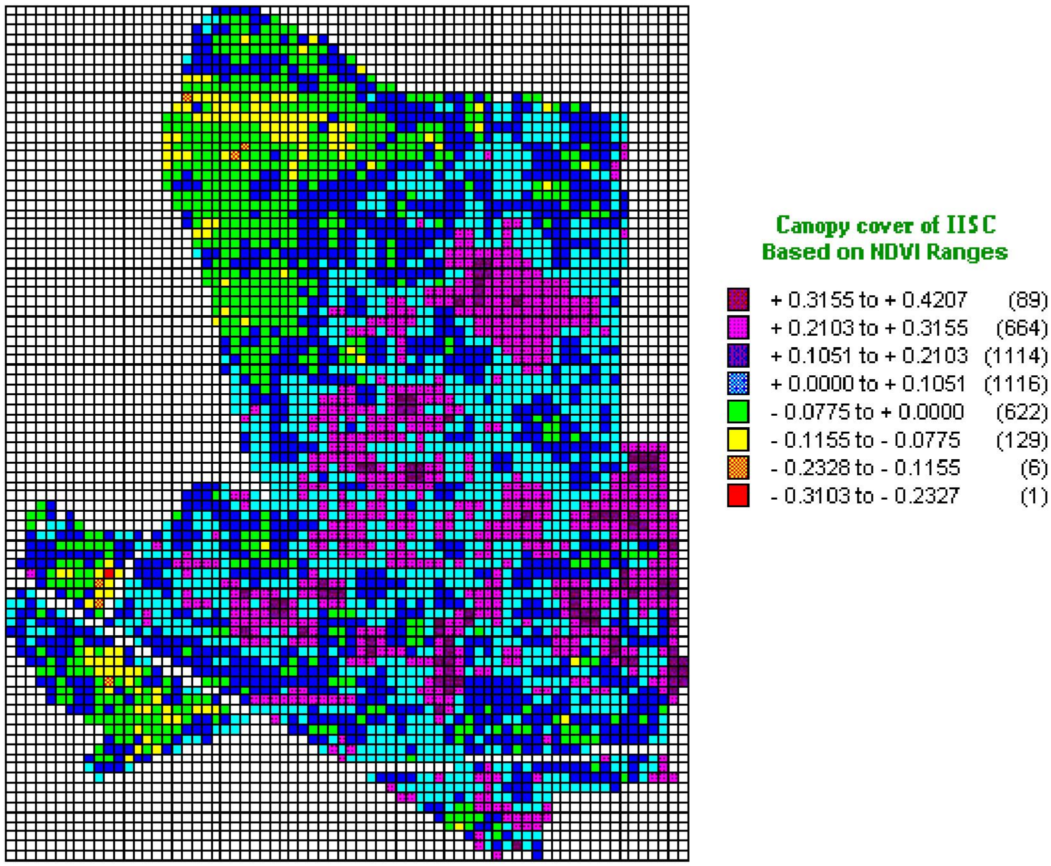


Figure 9: Tree Density (Trees per Hectare)

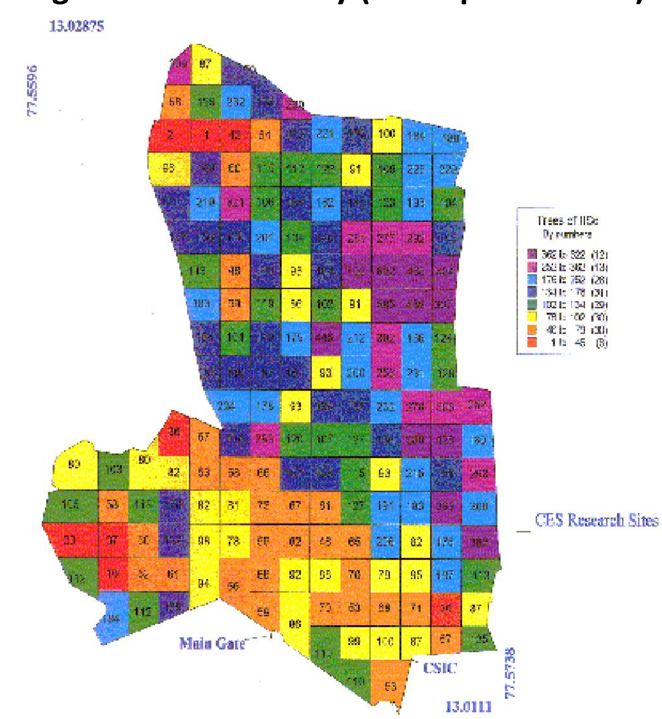


Figure 10: Species Density (Species per Hectare)

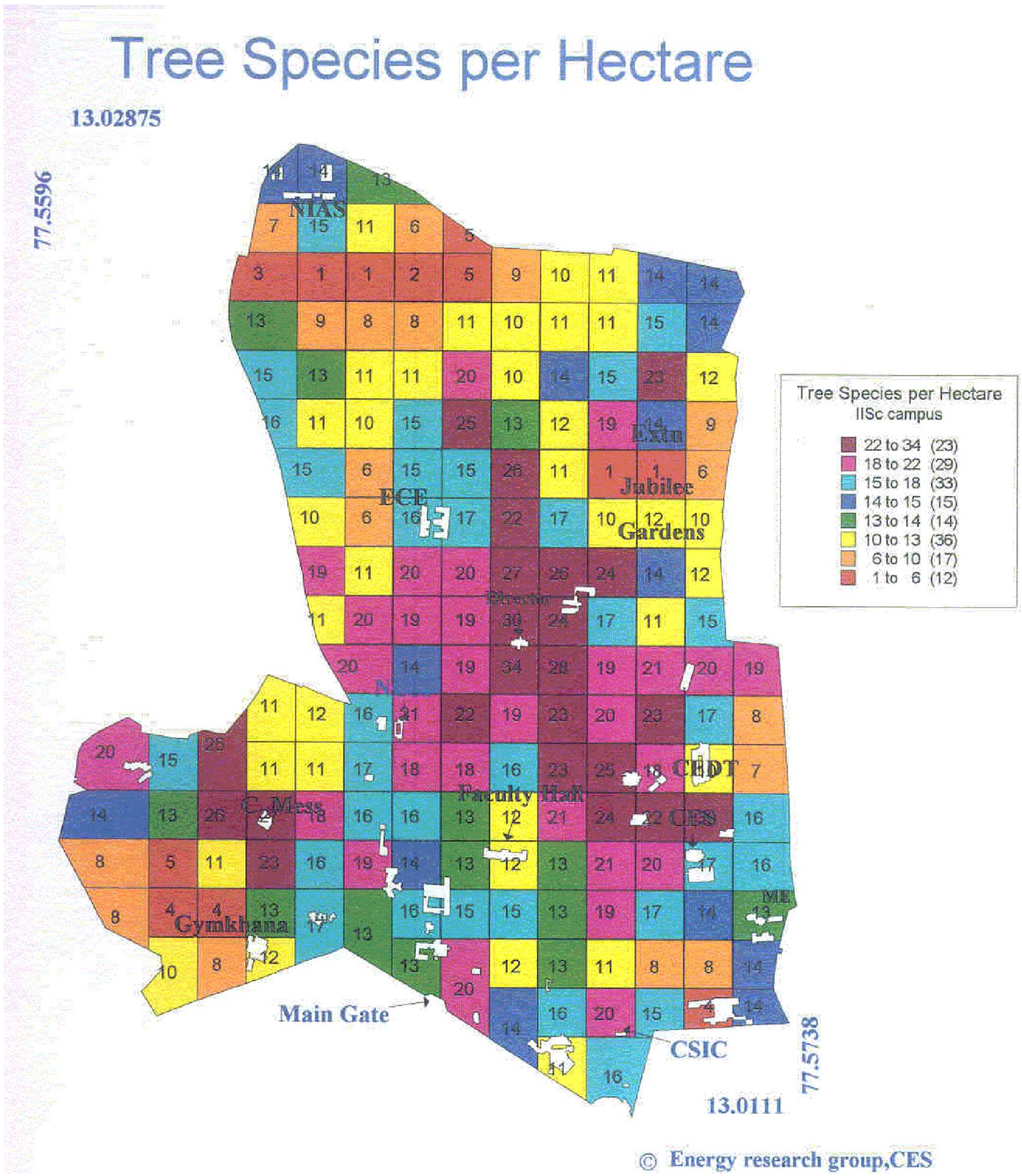


Figure 11: Species Diversity per Hectare(Shannon-Wierner Indices)

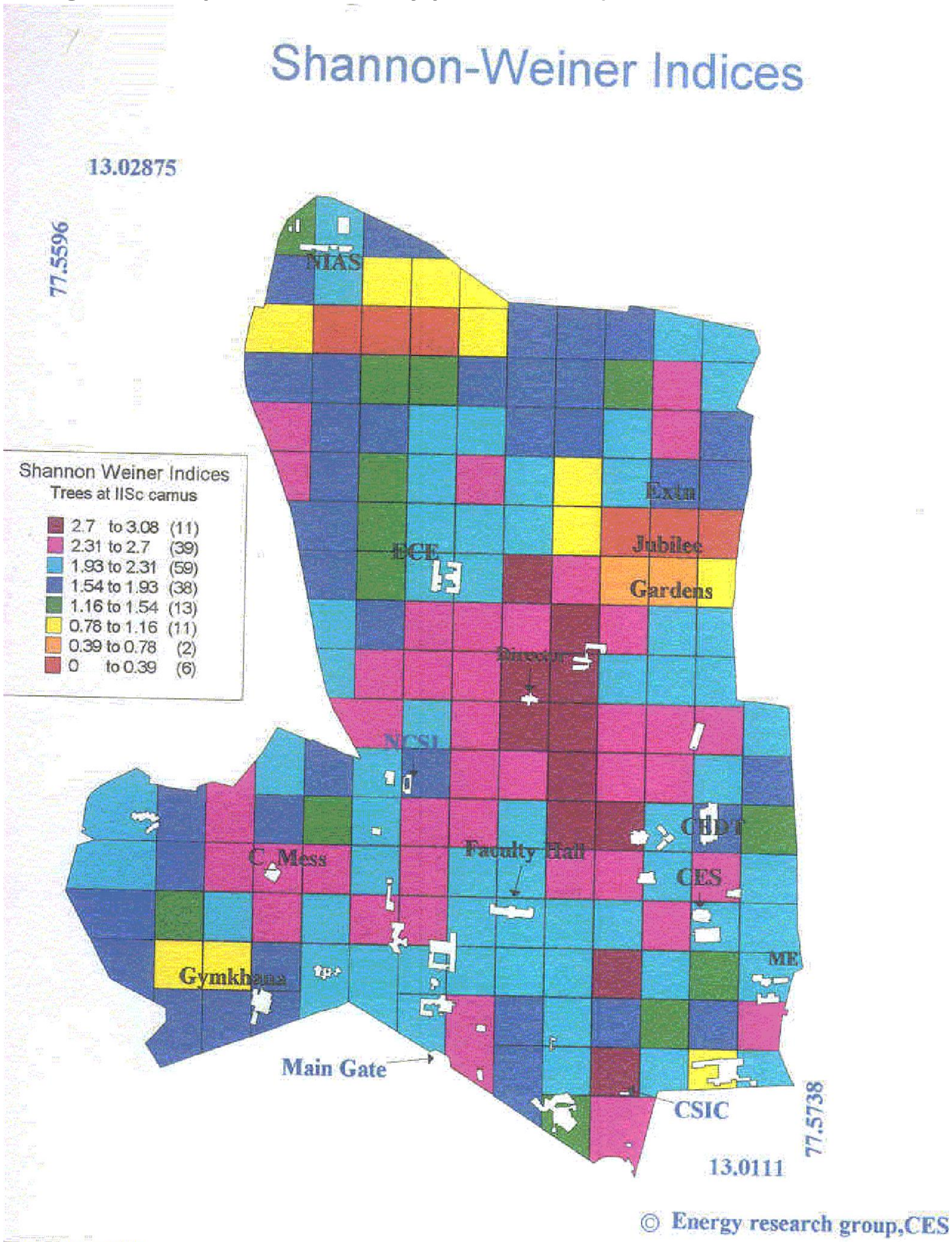


Figure 12: Zones of IISc Campus Based on Landuse Pattern with Spatial Spread of Buildings

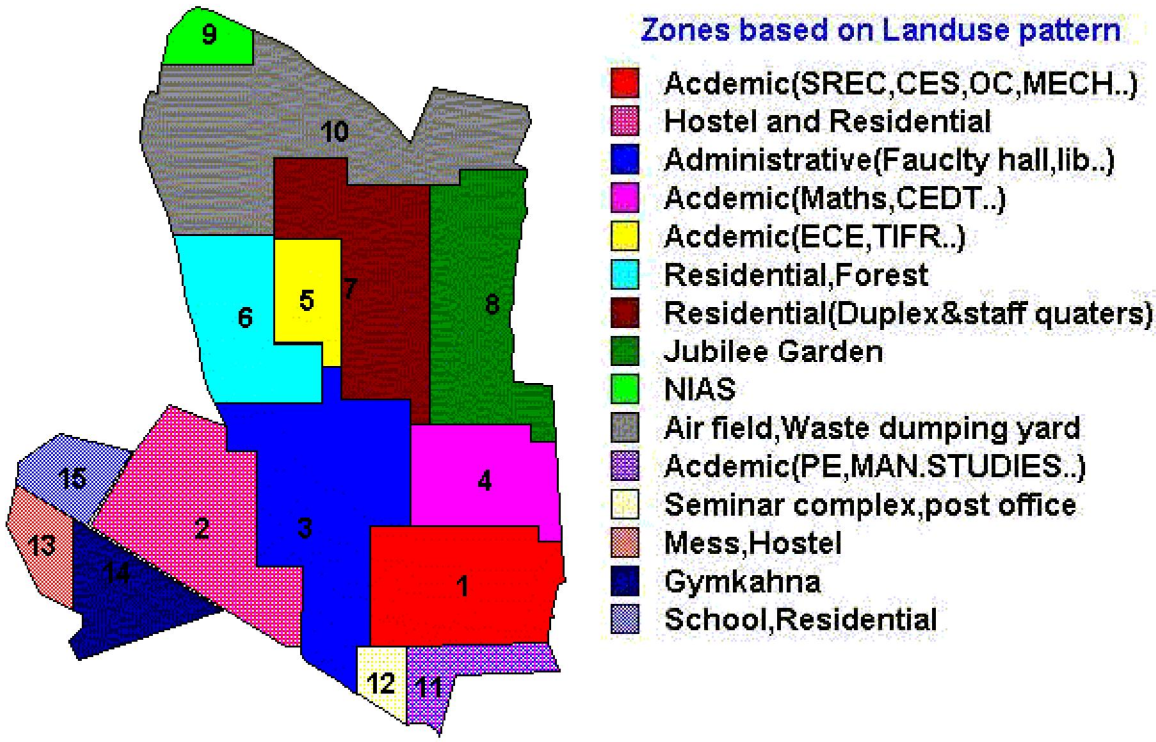


Figure 13: Zones of IISc Campus Based on Landuse Pattern with Spatial Spread of Buildings

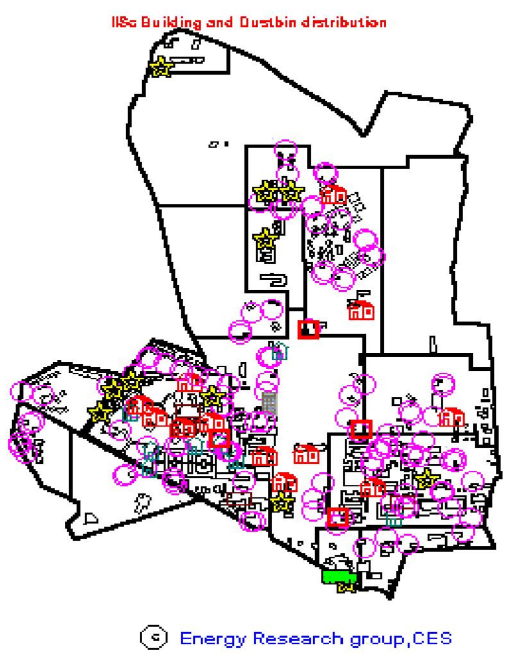


Figure 14: Locations where Collection Vehicles Collect the Waste

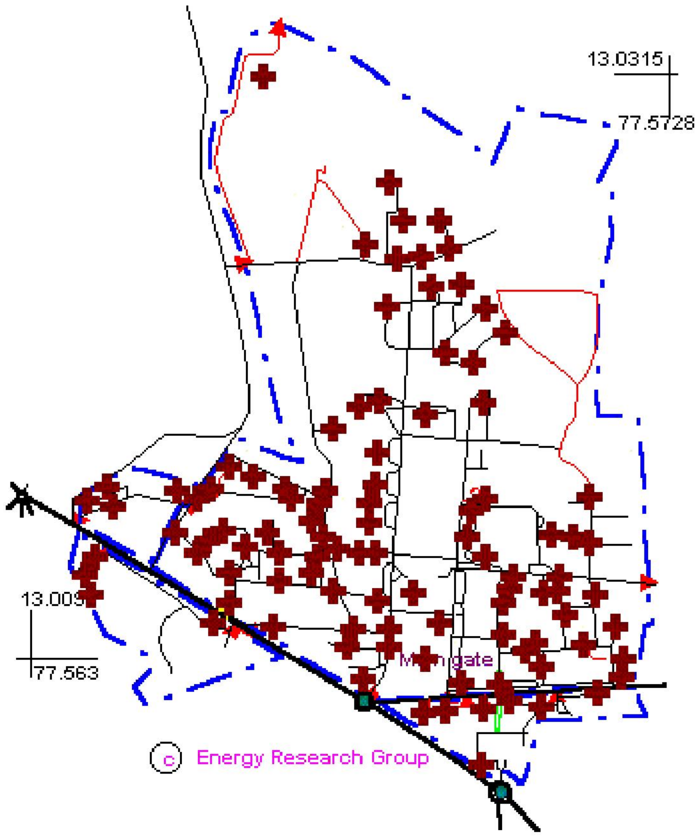


Figure 15: Thematic Map with All Zones and Proportion of Waste Generated

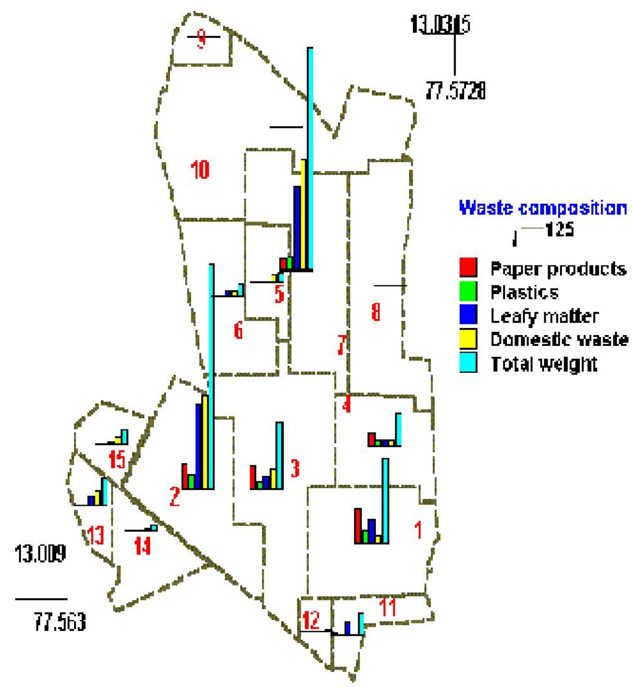


Figure 16: Map of Ltter Study Plots Sprawling Over Campus. The Plots were Located in the Map Using Global Positioning System(GPS)

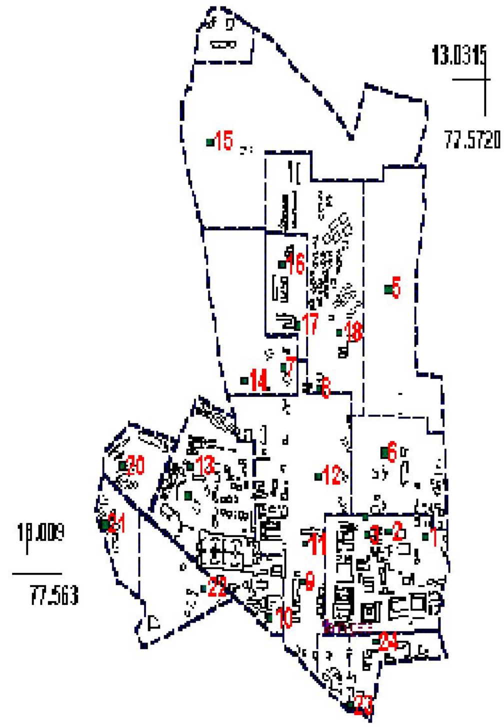


Figure 17: Optimal Route for Waste Collection Vehicle