CLASSIFICATION AND CHARACTERISATION OF DOMESTIC SOLID WASTES GENERATED IN JNU-MUNIRKA AREA

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MASTER OF PHILOSOPHY

SUNIL KUMAR

School of Environmental Sciences
Jawaharlal Nehru University
New Delhi 110 067
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जवाहरलाल नेहरु विश्वविद्यालय
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI - 110067

CERTIFICATE

This dissertation entitled "**Classification and Characterisation of Domestic Solid Wastes Generated in JNU-Munirka Area**", embodies the work carried out at the School of Environmental Sciences, Jawaharlal Nehru University, New Delhi. This work has not been submitted in part or full for any degree or diploma of any University.

SUNIL KUMAR
Candidate.

DR. A.K. BHATTACHARYYA
Supervisor

PROF. V. SUBRAMANIAN
Dean

July 1994

School of Environmental Sciences
Jawaharlal Nehru University
New Delhi-110067
INDIA

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Sunil Kumar

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(Sunil Kumar)

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CHAPTER 1

INTRODUCTION TO DOMESTIC SOLID WASTES

Indians are second to no other people in the world when it comes to personal cleanliness. Our habit of taking daily bath, washing our clothes, cleaning our houses, especially the kitchen, has traditionally been of the highest order. As a result of these activities huge amount and variety of waste is generated which is called "domestic waste". According to an estimate, our urban population of 110 million (1971 census) alone generated approximately 15 million tonnes of solid waste in a year.

In our daily lives, we use a variety of goods, which can be divided into two broad categories - **(1) edibles and (2) non-edibles.** Among edibles, we use a wide spectrum of foods, such as, cereals, pulses, milk, and various milk products, fresh and processed fruits, vegetables, oils, meat, etc. However, not all parts of these food materials are used for consumption and some parts such as fruit and vegetable peels, their rotten parts and seeds, bones, etc. are discarded and become wastes. Among non-edibles a wide variety of products are used which have been classified here in different categories :-

Category			**Description**
a.	Glass	-	bottles (primarily)
b.	Metal	-	cans, wire, foil, etc.
c.	Paper	-	various types

d. Plastics - PVC, polythene, styrene, etc. found in packaging, housewares, furniture, toys, and non-woven synthetic fabrics.

e. Leather, rubber, textiles, wood - shoes, bags, toys, etc. cellulosic, protein, woven synthetics, logs, twigs, etc.

f. Miscellaneous - inorganic ash, stones, dust

g. Yard wastes - grass, brush, shrub, trimmings.

Domestic solid waste: a part of the total Solid Waste of an area

In India, domestic waste is considered to be a part of the total municipal refuse being generated in a country for the sake of its management. In addition to domestic waste, municipal refuse consists of commercial refuse, street sweeping, construction and demolition debris, sanitation residues, institutional wastes, etc. Municipal solid waste in turn, is a part of the total solid waste being generated in a country which has been defined under substitute D of the Resource Conservation and Recovery Act (RCRA) of the U.S.A. as :- ...any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded materials including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining and agricultural operations and from community activities, but does not include solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act, as amended (86 Stat. 880), or source, special nuclear, or byproduct materials as defined by the Atomic Energy Act of 1954, as amended.

In accordance with the above-mentioned definition, the following categories of wastes have been identified :-

a) Municipal solid waste

b) Household hazardous waste

c) Municipal sludge

d) Municipal waste combustion ash

e) Infection waste

f) Waste tyres

g) Industrial non-hazardous waste

h) Very small quantity generator hazardous waste (> 100 kg/month)

i) Construction and demolition waste

j) Agricultural waste

k) Oil and gas waste

l) Mining waste

However, in India except municipal and industrial wastes, no other category of waste attracts much attention which is evident through a lack of data on them. Table below represents the per-capita generation amount of selected cities of India (1988):-

Per-capita Generation Amount of Selected cities (1988)

City	Population (thousand)	Generation (tons/day)	Per Capita Generation	Other
Bombay	9928	3600 (+1100)	362 gms	
Delhi	6900	2900	420 gms	
Ahmedabad	2917	1060 (+200)	363 gms	+bldg.dbrs
Coimbatore	868	130	150 gms	
Amritsar	650	600	920 gms	
Barailly	650	205	315 gms	
Ajmer	500	165 (+35)	330 gms	+bldg.dbrs +ind.waste
Nashik	482	100	207 gms	
Jamnagar	390	90	231 gms	
Mangalore	323	200	619 gms	
Chandernagar	149	14	94 gms	
Viramgam	52	17 (+3)	327 gms	+ind.waste
Sanand	25	10	400 gms	

Source : WHO, 1989

CHAPTER 2

STUDY OF THE CHARACTERISATION OF DOMESTIC SOLID WASTES - ITS IMPORTANCE

Domestic refuse is generated due to the activity of consumption of various types of commodities in households in an area. Not only the amounts of refuse generated person but also the characteristics of domestic refuse are related to this activity. The composition and properties of domestic waste reflects the full diversity of human activities within a household and vary mainly according to socio-economic status, food habits, local customs, geographical location, occupations and climatic conditions. Hence the study of the characteristics of domestic wastes generated in JNU-Munirka area will give us an idea of the consumption pattern of residents of this area.

Study of the composition of domestic wastes is a necessity due to the following reasons:

(i) **Unavailability of the separate data:** Though the characterisation of domestic wastes is highly important from the point of view of its management, it has not been studied separately from the general municipal waste in India. The municipal refuse is a composite of residential, market and commercial wastes. Hence its characteristics is expected to be quite different from that of domestic waste alone. Study of the characterisation of the domestic refuse of an area within a city becomes more important, where the number of households is much more than the number of markets and commercial complexes as the characteristics of the waste generated in this area will vary greatly from rest of the parts of that city. Our study area (JNU-Munirka area) represents that group which generates more of wastes coming out of households rather than those from commercial and market complexes.

In this case the idea of using municipal refuse data of that city in general, will not be a correct one for the purpose of the management of solid waste of that area as it will lead to an erroneous conclusion and hence an inefficient management. The following table shows variance in refuse composition by source of generation (in percentage by weight).

Type of material	Bandung,	Indonesia[1]		Colombo,	Sri Lanka[2]	
	Resi.	Market	Comm.	Resi.	Market	Comm
Paper	10	8	12	8	8	28
Glass, ceramics	<1	<1	<1	6	<1	8
Metals	2	<1	<1	1	<1	<1
Plastics	6	2	7	1	1	1
Leather, rubber	-	-	-	-	-	-
Textiles	4	<1	3	1	1	1
Wood, bones, straw	<1	<1	1	1	0	2
Non-food total	22	22	24	18	10	41
Vegetative, putrescible	72	84	69	80	88	58
Miscellâneous inerts	6	5	7	1	2	1
Compostable total	78	89	76	81	90	59
Total	100	100	100	100	100	100

Sources : 1 Llewlyn - Davies Kinhill Sycip Corres Vehay co. et al., Bandung urban development and sanitation project - Background papers - Solid waste, Republic of Indonesia, Ministry of Public Works, Directorate General of Housing, Building Planning and Urban Department, Cipta, Karya, 1979.

2 Cointreau, Sandra J. et al., solid Waste Management Plan for Colombo, Sri Lanka, National Water Supply and Drainage Board of Sri Lanka, 1982.

From the above table it is clear that the percentage of various components in wastes from three sources vary to a great extent. Hence, it is also quite essential to have a knowledge of the characteristics of domestic wastes along with the municipal refuse.

(ii) Essential in the selection of equipments: Knowledge of the characterisation of domestic waste is also essential while selecting proper equipments for transportation. One of the primary decision in equipment selection which refuse character would influence is whether compaction mechanisms on collection vehicles are cost-effective. Compaction vehicles are commonly designed to achieve a density of 400 kg/m^3. They therefore achieve a compaction ratio of 4:1 on refuse in industrialised countries, but only of 1.5:1 to 2.5:1 in developing countries. For example, rear-loading compaction trucks tested in Bangkok and Colombo achieved compaction ratios of 1.5:1 only.

(iii) Essential in the selection of proper disposal method

Knowledge of refuse character also helps in finding solid waste managers the most suitable disposal method. For example refuse having high organic content, low calorific value and high moisture content as found in JNU-Munirka area, is fit for composting. Its incineration will be very costly as it would require auxiliary fuel and a high technology. Sanitary landfilling can also be practiced as it is both cost-effective and environmentally safe. However, in developed countries, wastes with high calorific value, low compostable matter content, and low moisture content are fit for incineration.

(iv) Determination of the frequency of collection: Frequency of collection is affected by refuse character. In developing countries, where municipal waste is largely organic and exhibits relatively high moisture contents, where climates are warm, and where lining and yard space is limited, collection is needed more frequently than in industrialized countries. Collection every day or every two days is recommended.

(v) Essential in the projection of waste quality and quantify for the future: Character of domestic refuse changes with time and so it is very essential to make projections regarding waste quality and quantity for proper planning and budgeting. These forecasts are made with the aid of data for several years and hence the data of refuse composition needs to be obtained on a regular basis. However, in absence of this, we can make a good estimate by studying the relationship between refuse character and quantity and standards of living, provided if we have data on refuse composition from households in different income groups. As the proportion of the community in each socio-economic stratum changes, refuse from that community will also change.

With the above mentioned benefits in mind, it was decided to carry out a study of the domestic waste generated in the JNU campus and adjoining Munirka area. This study involved both physical and chemical characterisations of domestic wastes from these two areas. Several conclusions were drawn from the analysis of the data obtained which might be useful in giving suggestion regarding appropriate management of the domestic waste of these two areas.

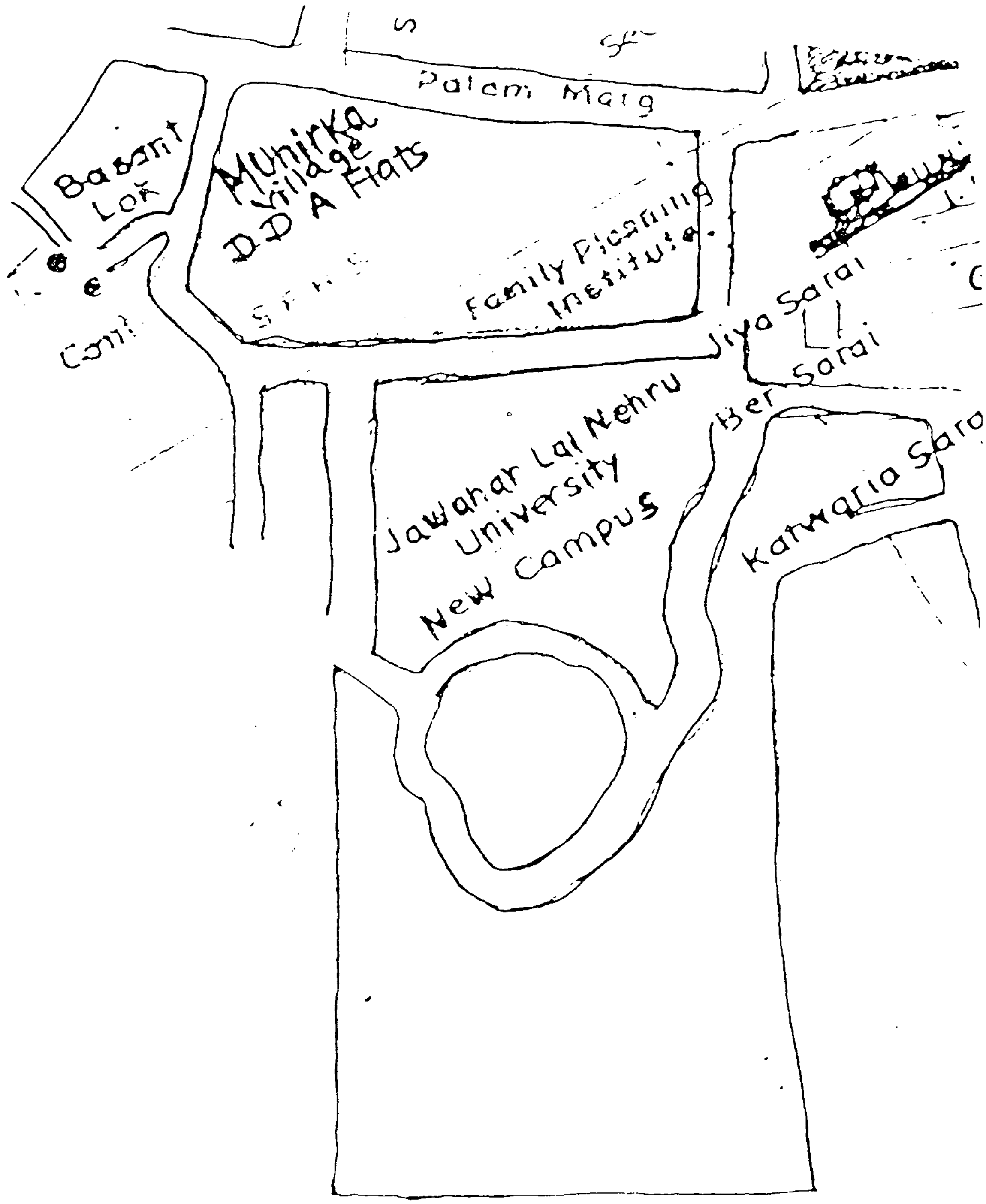
CHAPTER 3

DESCRIPTION OF THE STUDY - SITES

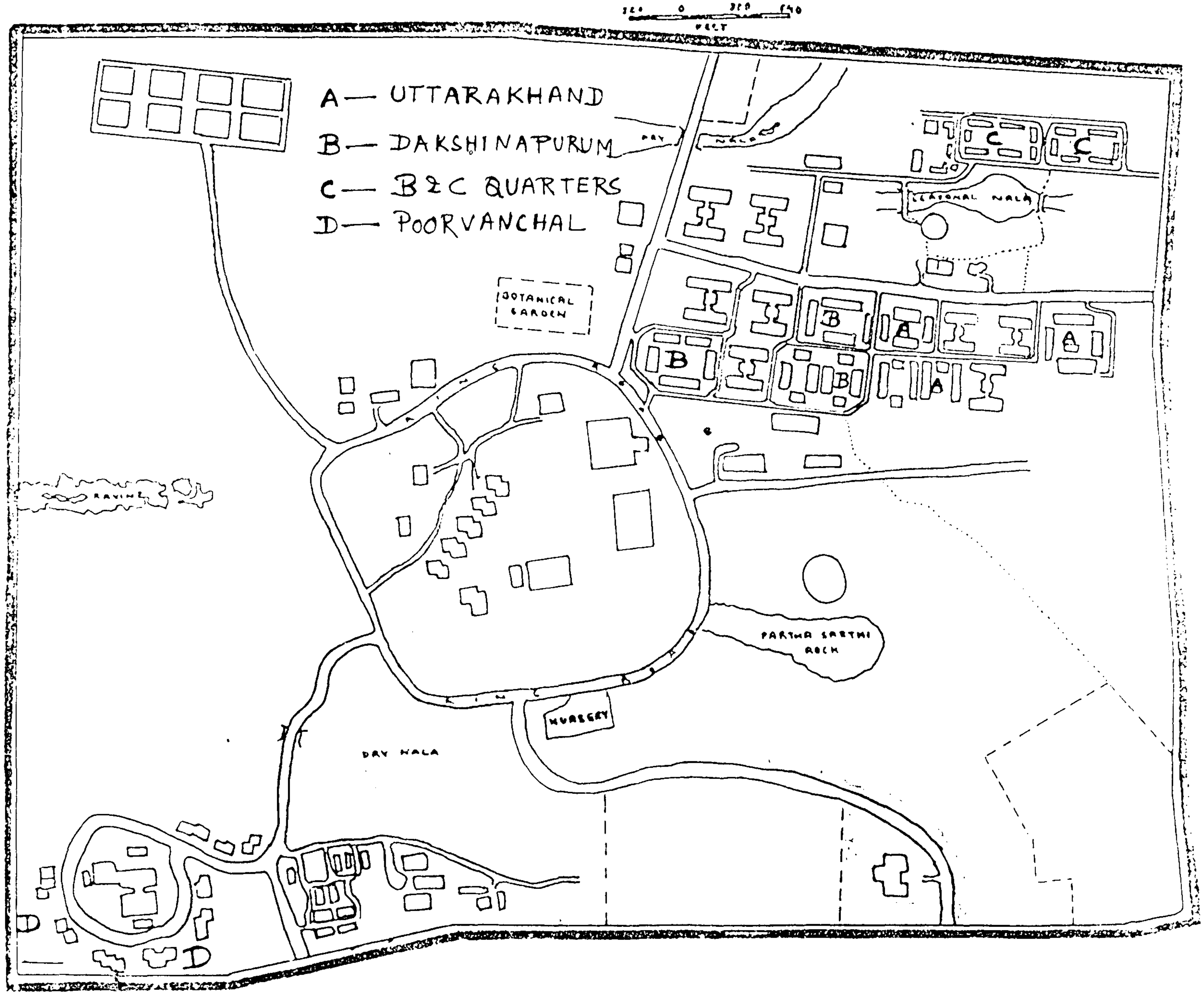
The Study area, defined as JNU-Munirka area is located in the south of New Delhi, the Indian Capital. Delhi covers an area of 1483 km^2 with the greatest length and width being 51.9km and 48.8kms. Delhi is located between 28°53'00" north latitude to 77°22'37" east longitude. Population density of Delhi is 4194 and the total population is 9420644 (1991 census). Within this region, JNU (Jawaharlal Nehru University) campus and Munirka occupy areas of 2.42 and 1.45 km^2 respectively. The boundary of JNU is marked by Katwaria Sarai in the east, Vasant Vihar in the west, Munirka in the north and by Masudpur in the south. The boundary of Munirka is marked by Qutub Enclave area in the east, Vasant Vihar in the west, R.K. Puram in the north and JNU campus in the south.

Employment - Since JNU is an educational institution, all working people living inside the campus are the university employees. Some outsiders do business in the campus during day and evening time. In Munirka, a mixed population representing different employment categories are found. Both skilled and unskilled labourers are found. Some are government employees while some are businessmen. Among government employees, some are technical persons while most of them belong to non-technical background.

MAP OF JNU & MUNIRKA



JAWAHARLAL NEHRU UNIVERSITY
CAMPUS MAP



Climate - The climate is tropical with temperature varying between the mean minimum of 7.8°C in January to the mean maximum of 40.5°C in June. Mean annual relative humidity is 17.7%. Rainfall occurs during July and August with average annual rainfall of 55mm.

Health - Medical facility is available to the residents of both JNU and Munirka area. Viral fever and malaria are the most common diseases prevalent in this region. This is due to the bad drainage condition in Munirka. There are open sewers in which the larva of mosquitoes flourish and cause malaria. Diseases related to dirty drinking water are also very common because of the seepage of drain water into the pipes carrying drinking water. But due to the access to good government hospitals and local private-practicing doctors, death does not occur frequently. Death rate in 1981 was reported to be 7.2 per 1000 and infant mortality 65 per 1000 live births. During the same period in India, comparable figures were 11 per 1000, and 96 per 1000, respectively.

Residential plan (a) Munirka - There are, generally speaking, two categories of housing: formal and informal. Formal housings which conforms to planning and building regulations houses high-income group Munirka residents and is represented by DDA flats. Informal housing has been built without assistance from formal institutions and buildings enterprises and has developed independently of official standards and regulations. All houses in Munirka village belong to this category, as earlier this area was not within the jurisdiction of the Municipal Corporation of Delhi (MCD).

Previously it was a village and only later it was brought within the boundary of Delhi during the expansion of this city. Many households have been assessed to be in shared accommodation. Recently, within the last 15 years, lot of formal houses (flats) have been built by the Delhi Development Authority (DDA) meant for the high-income group residents.

(b) JNU Campus - Only formal housing is found in JNU campus. All the houses have been built by the university authority. Three broad categories of residents exist here : (1) students, (2) faculty members, and (3) non-teaching employees. Students live in hostels. Separate quarters are there for the faculty members, while B & C flats house the university's non-teaching employees.

Roads - While the capacity of the road-system is quite adequate for the volume of traffic in JNU campus, it is woefully poor in Munirka village area for the reasons such as lack of space (width of road), pavements, lay-bys, car parking facilities, and an overall road hierarchy causing congestion. Non-motorised traffic and numerous street vendors effectively reduce the carrying capacity of the road system. However, roads encircling DDA flats are quite wide. Parking facility is not satisfactory. Hence there is less congestion in this sub-area. Excellent road-system in JNU campus eliminates all traffic problems. Data is unavailable regarding the number of different categories of vehicles in these two areas. However a large number of them are seen here because of the presence of high-income group people in these two localities.

Water supply - The public water supply is available to 100% of the population belonging to these two areas except the village area of Munirka. While good water quality is available to JNU campus residents, the same cannot be expected of the Munirka area due to the reason mentioned above. 100% of the daily supply comes from the Yamuna river through several pumping stations belonging to the MCD.

Sewerage - JNU Campus is well served by an underground sewer system. Since the campus is built on uneven surfaces of old Aravali hills, lot of slope is found which give adequate flow to the sewage and hence even in the absence of sewage treatment works, none of the problems is encountered here.

While Munirka DDA flats and some pats of Munirka village are served by a municipal trunk sewer system, most of the village area is served by concrete-lined open channels. A sewage treatment works gives adequate treatment to the flow in municipal sewer system. However, open channels found in the village area are served by poorly constructed and unlined channels with inadequate gradients resulting in blockages and sections containing septic sewage

Drainage - Excellent drainage condition exists in JNU campus because of its location on slopy hill surfaces. This provides automatic downward flow of rainwater. The main road has been lined with concrete channel on its both sides which prevents any water logging.

Munirka DDA flats have been provided with underground sewer system which collect drainwater from all sides. Hence adequate drainage system seems to exist here. However Munirka village is not having proper drainage system. Though sewer system exists along with open channels, still this area experiences some water logging during rainy season. This is due to the fact that channels are poorly constructed with inadequate gradients and are always choked with various waste materials. This prevents free flow of water and leads to water logging. Village streets are very narrow and are not asphalt made. Hence many pot holes are found in which rainwater gets collected. Dumping of solid waste, encroachment on the waterway by buildings and other human activities further reduce the effective capacity of the existing drainage system.

Solid waste management aspects in JNU-Munirka area

The existing system - As with most solid waste management systems, in JNU-Munirka area the operation involves storage, collection, transfer, transportation and disposal. The main sources of wastes are residential areas, markets and commercial premises/streets. The collection system is provided by the Municipal Corporation of Delhi (MCD). The municipal corporation, headed by elected mayors, consists of three main executive authorities, i.e.

i) the elected general council of the corporation,

ii) the standing and financial committee, and

iii) the commissioner, who is the chief executive of the corporation

Such a situation is established under a specific state enactment for major and important cities and is bestowed with a certain degree of independence and autonomy in mobilising resources and providing local services in the matters of public health, sanitation, water supply, sewerage/drainage, solid waste management, roads etc. In Delhi management of solid waste is the sole responsibility of the MCD which collects, transfers, transports and disposes of solid waste. Waste produced from individual households is removed initially by the owner or an employee and later by the municipal staff. In the case of transfer depot system adopted in most of the areas of JNU and Munirka, waste is collected and taken to the transfer depot by the houseowner or an employee from where it is removed by the conservancy staff. Wastes from the streets are collected and removed by the conservancy staff.

Storage - It is the first step in solid waste management which is performed by the house owner. Storing solid wastes prior to collection prevents offending aesthetic tastes, attraction of vectors, and excessive odors. Storage devices should be convenient for the user and facilitate safe, efficient collection, processing and disposal. In JNU-Munirka area storage is done in houses by using plastic and paper bags or buckets of 15-20 litre capacity. Use of plastic and paper bags and holders offers certain advantages and disadvantages. Among the advantages are:

1. one way disposal without retrieval,
2. an universal and standard size, cleaner container,
3. faster collections because they do not have to be uncovered and returned after

being emptied,

4. reduced spillage and resultant litter,

5. easier storage and handling as liners or in suspended bags holders,

6. reduced back-strains and similar collector and user injuries is because bags are far lighter, will not hold heavy loads and are easier to handle than rigid cans;

7. more sanitary and cause less noise, dust, odor and microorganisms release, and adoptable to mechanized collection by truck equipment.

In summary, plastic bags are similar to store, more expandable, less expensive and are easier to tie and handle then comparable paper bags. However, both paper and plastic bags are more easily punctured by sharp objects and dogs, racoons, rats and the like can tear these open. Bags are a continuing cost and contribute to solid waste in themselves. Hence one of the pre-requisites in the chain of activities that must be properly carried out in order to have an efficient and sanitary management of solid waste is proper storage in the premises where the waste is generated. Another aspect of the refuge storage problem is the commercial refuse. Traders litter the markets and the shopping centres. thereby making sanitary refuse collection difficult for the MCD.

Refuse collection from premises - Refuse collection is the most difficult and most expensive aspect of solid waste management. It is highly complicated because house to house collection is not possible. In JNU-Munirka area, people usually take out wastes twice daily i.e. in morning and evening from their houses and dump them either in a concrete made transfer-depot or in other open spaces. Transferring domestic waste from houses to transfer-depots is prevalent in JNU campus and DDA flats in Munirka which have been built by the MCD. However, Munirka village does not have this facility and hence the village residents dump their domestic wastes in open spaces where they lie uncovered and become excellent breeding place for flies and other vectors as well as various types of human intestinal parasites such as A. lumbricoides and T. trichiura. Heaps of domestic wastes can be found in many areas of the Munirka village. Some of the refuse is also deposited on the adjacent road side from where it is collected during sweeping of the roads.

People are reluctant to store the waste inside the house. Most houses do not have large open spaces where it can be stored. This poses problem in adopting a house-to-house collection system in JNU-Munirka area. Due to low purchasing power, people here are not able to purchase and maintain standardized containers for use in such a system. Though in both JNU and Munirka areas, multi-storey buildings could have been provided with standardized containers but the MCD has not done so probably because of large capital cost and effort involved in purchasing and maintaining an inventory of the containers.

Collection of waste from streets - In addition to waste generated in individual premises, wastes are also generated on streets, the collection of which is the responsibility of the MCD. City streets should be kept clean for many reasons:

1. to prevent disease, injury and annoyance from street dirt,
2. to prevent vehicle damage from sharp, metallic objects,
3. to promote safety in reducing fires from dry leaves and litter, and slips and skids from wet leaves or fruit peels,
4. to enhance community appearance,
5. to prevent the clogging of sewers and storm drains, and
6. to reduce water pollution from street run-off.

Though a proper solid waste collection system helps reduce street dirt and litter, but some street cleaning is still required. In JNU Munirka area, sweeping of the roads is carried out manually. This seems to have an edge over the mechanised road sweeping due to low capital cost, high cleansing efficiency and a lesser need for replacement of brushes due to lower rate of wear and tear.

In JNU-Munirka area, labourers work in gangs. Every worker has been assigned a specific area. Sweeping of the roads is carried out by using a short handled broom made out of a brush of fibres. The sweepings are taken to the street gulley from where they are removed using a stout hard push brush and then lifted from corners by a flat blade shovel. While doing the work, the labourer has to bend which (i) strains his back and (ii) exposes him to the dust which gets airborne during the sweeping operation. The material so removed from the road surfaces and gullies is collected in heaps at a number of points from where it is conveyed in a wheel barrow to the nearest transfer depot.

The design of the wheel barrows has not been standardized and different types of two-wheeled barrows are used. The capacity of the wheel barrow varies from 50 to 100 litres. Recently a three-wheeled barrow with a castor wheel has been introduced which is expected to find a wider acceptance.

Equipment for street cleansing -

The equipment in use for manual cleaning in JNU-Munirka area consists of brooms, shovels and handcarts.

1. **Brooms:** Two types are used: (a) one consists of a bunch of long and flexible fibres and is used by the workers standing erect. The brooms are used with long strikes without exerting much pressure and are good for sweeping light materials like sand silt but workers prefer this due to lesser exertion.

(b) The second consists of a wooden handle to which a large number of short rufts or filaments are bound. The worker bends a little and gives short but vigorous strokes for cleaning. As the greater forced is exerted, heavy dirt and silt get dislodged. It is straneous for the worker and if used indiscriminately large amount of dust will get air-borne posing danger to the health of the workers. Small brooms or wire brushes are used for cleaning of channels.

2. **Shovels:** The material collected at a place needs to be lifted which is carried out by using a shovel. Conventionally, a straight blade shovel is used for this purpose, but is observed that light materials like tree leaves, paper etc., tend to fall off. Flat boards made of G.I. sheets are also used which are found to be better.

3. **Hand carts:** In our study area, two-wheeled wheel barrows are used. Here the worker has to exert both horizontal and vertical forces for transporting the material. Use of three-wheeled hand cart would have been useful as it does not require vertical force.

Transfer depots - Though the community bin system is the most widely used one in India, in our study site (JNU-Munirka) transfer deposits are used instead. This is built by the MCD at frequent intervals along the roadside. Residents take out wastes from their houses and deposit in these transfer depots. Since in these areas, density is very high and hence the refuse quantity is also high, use of transfer deposits is quite justified. These transfer depots are large masonary structures known as vats. They consists of a three-sided concrete structure, upto 10 m^3 capacity, but are also as small as 2 m^3. They have a low wall (about 1m high) on the roadside and a high masonary wall (2m high) about 2 m away from it. Workers with hand-carts enter the space from the open side to deposit the waste. The transport vehicle which stands adjacent to the low wall, is filled by hand by workers climbing the steps provided on the inner side of the low wall of the vats. They are satisfactory, except that the enclosed space is observed to be incompletely utilised. The arrangements are unhygienic and restrict traffic movement; the location of transfer depots is somewhat arbitrary. The waste also has a free access to rats, flies, birds and rag pickers. In course of time, this place turns insanitary due to nuisance.

Frequency of collection - The large organic fraction contained in the refuse of JNU-Munirka area tend to decompose quickly at the high temperatures encountered if not removed quickly. It has also been observed that if the waste is not removed quickly, fly larva contained in the refuse develop into flies. Keeping in mind these issues, the MCD authority has made arrangements to collect the waste twice a week.

Transfer of waste from vat to transport vehicle

Every refuse vehicle is provided with 4-6 labourers in addition to its crew. The vehicle moves and collects refuse from one vat to the next until it is full. At the vat, workers from the vehicle get down, collect the contents of the vat in baskets and transfer it to the vehicle. After the vat is completely emptied, the vehicle moves ahead for collection at the next vat.The routes along which the vehicles move are fixed on the judgement of the supervisory staff; optimisation of routes has not been attempted on a rational basis.

Transportation of refuse

The transport of collected waste is frequently a major problem in cities like Delhi because of the combined effects of very heavy traffic and small payload vehicles. This means that a high proportion of vehicle operating time is spent on transporting wastes to the disposal site. Transportation of refuse is carried out by the MCD. The refuse collected at the roadside vats are collected and transported to the processing and disposal site by using a tractor-trailers and open trucks. The vehicle makes a number of trips everyday to the disposal site. Though instructions are given to the vehicle operator to collect wastes from specific collection points, it is not uncommon to see that the vehicle is simply directed to collect waste from a ward or an area. This work can be carried out more effectively with the use of available funds, vehicles and staff by adopting better techniques. Following are the descriptions of refuse transporting vehicles.

(i) **Tractor-trailer -** Tractor trailers due to low initial cost and ease of operation are used in the JNU-Munirka area. Here the tractor trailer is used as one unit and hence the operation can not be said to be an economic as compared to the situation where tractors are used to pull trailor parked at different locations. As the tractor has a small wheel base it has good manourvability enabling it to negotiate sharp turns in narrow streets and bylanes. The trailers used in JNU-Munirka area are of open type, i.e. no enclosure is provided to prevent access of pickers, stray animals and rain to solid wastes. The tractors have the following drawbacks:

(a) They are designed for high torque and low speed which limits its operation at high speed and results in larger wear and tear.

(b) The tyres of the tractors are designed for use on farms and are of mud grip type which wear out faster on city streets.

(c) The breaking system is more efficient at low speed and when operated at higher speed, it tends to lose road grip and skid.

(d) There is no protection to the driver from rain and dust.

(ii) Trucks - Trucks of 5 tonnes capacity are used in our study area. These tricks make 2 trips per day covering about 50 km per trip. MCD uses only old trucks for transportation of refuse. This results in high cost of maintenance and high cost of operation. Refuse is a low density material with the result that 5 tonne truck seldom carries more than 2-3 tonnes of refuse. The body design needs to be modified to increase its carrying capacity.

Problems affecting refuse transportation

Following are the factors that make efficient refuse transportation difficult in JNU-Munirka area: -

(a) Nature of refuse: Refuse in JNU-Munirka area has a very high organic content. Therefore refuse cannot be compacted so that it occupies less space in collection vehicle, as is normally the case with less dense refuse from the developed countries. This prevents MCD from using compaction vehicles as it would not be of any noticeable advantage.

(b) Traffic situation: Except around DDA flats, the roads in Munirka are so narrow and congested that the refuse collection and transportation are seriously affected. Since the refuse vehicles are of open type, dust, ash, etc., from wastes on vehicles become air-borne affecting people moving on roads or standing on road-sides. Night refuse collection avoids this problem to a large extent.

(c) Shortage of refuse vehicles: This is the greatest problem MCD faces in efficient transportation of refuse. It has hardly 50% of the actual number needed. Another problem is that the MCD uses many makes of tractors which complicates maintenance and provision of spare parts.

(d) Shortage of funds: This factor seems to prevent the MCD from providing efficient services. In the absence of funds, collection and transportation are affected most. Scarcity of funds for refuse disposal is due to (i) an inefficient revenue-collecting system, (ii) poor budgeting, and (iii) mismanagement of the meagre available funds.

(e) Distance of the disposal site: It is about 25 kms from Munirka and hence not more than 2 trips/day is performed by the tractors and trailors. This increases the cost of operation. Though compaction of refuse into blocks would have been an economical practice but highly organic nature of the waste renders it difficult.

Disposal

Disposal of solid wastes by dumping in low lying areas has been practiced since early times. More than 90% of urban solid waste in Indian cities and towns is disposed of by landfilling and only a minor fraction, about 10%, is composted for producing organic manure and soil conditioner. Waste generated in JNU-Munirka area with a low calorific value, a high moisture content a high quantity of non-combustibles, is not suitable for incineration. Apart from a high initial cost, it would need a large quantity of auxiliary fuel. Few years back, an incineration plant was set up in Delhi. It ran for a very short time and has been out of operation since then. So incineration is certainly not the answer to the waste disposal problem of the JNU-Munirka area. Keeping in mind both cost and environmental protection, sanitary landfilling has been choosen as the most suitable disposal method by the MCD. Sanitary landfilling has been defined as a "method of disposing of refuse on land without creating nuisance or hazards to public health or safety, by utilising the principles of engineering to confine the refuse to the smallest possible area, to reduce it to the smallest practical volume and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as may be necessary". Thus the method essentially consists of laying the material systematically followed by its compaction to smallest practical volume with least exposed area and then covering it with soil. As it is compacted, further decrease in volume will not be very large. As the exposed surface area will be the smallest the amount of soil cover needed will be small which is not an important consideration, especially when the soil cover has to be brought from outside as in our case. Covering of the waste with soil or other inorganic material makes it inaccessible to flies and rodents and the heat released during decomposition is conserved, increasing the chances of destruction of fly larva and pathogenic organisms.

Only in one of the nine metropolitan city centres, the MCD has developed sanitary landfilling sites. MCD disposes of 90% of its daily collection of 1500 tonnes of solid waste in four major disposal grounds. All the sites have good approach roads and average haulage is within 15 kms. They all have the necessary facility of weighing, mechanical handling of refuse and earth, watering and washing, etc. The areas filled up with refuse are regularly covered with fresh earth and other precautions like spraying of insecticides for fly control are also taken. Disposal sites, so filled are being developed into parks and woodlands. Due to the geological nature of the land landfill sites being impermeable and due to very limited rainfall in the city, the percolation of leachate to ground water is almost nil. Therefore groundwater is not being contaminated. Since sufficient land is available for disposal, this refusal is also best in the sense that it is most economical refuse disposal method. It is also of simple design and easy to implement. It does not need special expertise, like other methods of disposal such as mechanical incineration or resource recovery of refuse. Thus the method of sanitary landfill adopted by the MCD seems to be the most suitable one for the disposal of refuse generated in JNU-Munirka area.

In sanitary landfills, area method is adopted as it is highly suitable for areas where natural depressions exist as in queries, ravines and valleys. The waste is put in the natural depressions and compacted. A layer of earth is given on top and compacted. The process is repeated till the depression is filled up. The earth cover is imported from elsewhere.

CHAPTER 4

DOMESTIC WASTE SAMPLE COLLECTION

Study areas and the criteria for their selection

Domestic solid waste samples were collected from all four residential sectors in JNU campus and from two major areas in Munirka. These four sectors in JNU campus are:

1.	Poorvanchal	2.	Uttarakhand
3.	Dakshinapuram	4.	B & C quarters

All these four sectors represent formal housing only as no informal housing is found here. First three sectors include 10 hostels, meant for students' accommodation, 190 quarters for faculty members and high ranking university administration officials and a small market complex. The last sector i.e. B & C quarters are meant for lower ranking university administration employees. Since this particular study is concerned only with domestic wastes, samples were not taken from the hostels and the market complex though they produce a good chunk of wastes.

Samples collected from the two major areas in Munirka are:

1. Munirka village - representing informal housing and middle income group

residents, and

2. DDA flat areas - representing formal housing and high income group residents. Following criteria were followed for the selection of study areas.

(i) **Proper representation of all residential segments:** Study areas were selected in such a way that they represented all residential sectors within JNU campus and Munirka area.

(ii) **Proper representation of residents belonging to different income-groups:** Study areas were also chosen in a way to represent residents belonging to different income groups. While B & C quarters in JNU campus and Munirka village in Munirka represented middle class areas, rest other areas (Uttarakhand, Dakshinapuram and Poorvanchal) in JNU campus and DDA flat areas in Munirka represented high income group areas.

(iii) **Representation of formal and informal housing:** Study areas selected included both formal and informal housing. While Munirka village represented informal housing, DDA flat areas represented formal housing. Incidentally, these two areas also represented two different income groups as mentioned above.

(iv) **Cooperation and interest by residents:** Only those houses were selected whose occupants showed some cooperation and interest in this study. This was considered necessary as without their cooperation, collection of real data would have been difficult.

Methodology of Sample Collection

Domestic waste samples from five houses were collected from each designated study areas in JNU campus and Munirka area in different months of the year 1993 and 1994. Samples were collected in the late evening to ensure collection of total waste generated in a day in each house. While collecting samples, the number of residents in each house was recorded. This was done to get the data on volume and weight per person per day. Samples collected from each house were put separately in polythene bags and the date of collection, location of the source and the name of the house owner and house number (if any) were recorded on each of them.

This technique resulted in samples of between 7 and 9 kgs. American research indicated that 90 kg was the maximum satisfactory sample size. But if the number of households contributing is regarded as more significant than the sample weight, it is clear that 7 kg was a satisfactory sample for JNU campus and Munirka area since this came from 30 houses whereas 90 kg from a once-weekly collection in the U.S. could come from as few as 15-18 households.

After collecting waste samples, following studies were done with them:

1. Determination of moisture
2. Physical analysis of waste, and
3. Chemical analysis of waste

Standard methodologies followed for the analysis of the above mentioned things have been discussed in the next chapter.

Common practices affecting the collection of real domestic waste data

There are various activities practiced by the owners of households in the study areas which might have interfered with the collection of actual waste data. As the incomes of middle-class families were not great, items that had some utility values still intact or those that could have gained some income to them, were not given for sampling or discarded or solid waste. For example, empty bottles were always retained for reuse or sold to kabariwallahs. Similarly, newspapers, iron or tin containers, card-boards and other similar items were also sold to kabariwallahs even for a small amount. This practice was found to be prevalent even among high income group people. Another practice which affected the data regarding chemical characterisation of wastes in this study was the discarding of dust and other fine inerts before handing over wastes to the collector. It was found to be a common practice in all households. People preferred to throw away dust instead of collecting it in polythene bags and giving them to the waste collector. As a result of this practice, the %age weight of dust and other fine inerts was so small that they were considered to be unimportant waste constituent and hence not considered in our study.

CHAPTER 5

MATERIALS AND METHODS

All the methods for physical and chemical analyses of the samples were followed as per Bureau of Indian Standards guidelines.

(1) Physical Analysis

Procedure: Domestic waste samples were deposited on a plastic sheet of 1 square meter area to conserve the dust and moisture. The material was then sorted into its constituents. Each component was put in a separate bin and weighed. The weights were then expressed as percent of the original sample.

The categories choosen were: (a) food wastes and foliage, (b) paper; (c) plastic, rubber and polythene; (d) metal, and (e) textiles.

The weight of material in each category was measured using a spring balance reading upto 5 kg. Weights and observations on the nature of the material were recorded.

The separated material was further segregated into organic and inorganic portion. The organic portion mainly consisted of paper, plastics, rubber and textiles. The inorganic residue consists almost exclusively of metals. Separate weights were taken of each category and were expressed as percentage of the total crude sample.

Density measurements were made separately by loading a 1-litre beaker and recording the weight of the crude sample occupying this much volume.

Determination of Moisture

Procedure: In order to determine the moisture content, the entire crude sample was weighed. Then it was spread thinly and dried in a drying oven till its mass become constant. Drying was done at 105°C for an overnight. Since the dried crude sample were somewhat hygroscopic, they were left to cool in a turned off drying oven and weighed immediately afterwards.

Calculation:

$$M = (a - b)/a \times 100$$

where,

M = Moisture content of the crude sample, percent by mass

a = Net wet mass,

b = Net dried mass

(2) Chemical Analysis

Sample preparation for analysis: The three basic operations followed to prepare the sample for detailed analysis were drying, grinding or pulverising and mixing. Following are the detailed accounts of each of these three steps:

Drying: A laboratory oven was used for drying samples. A pan was weighed, material was transferred to it and it was again reweighed. This gave the weight of the material which was put inside the oven at 105°C for 24 hours. After this, the sample was allowed to cool in a desiccator. It was again weighed and again placed in the oven. This process of heating, cooling and weighing was repeated till the difference in mass between two successive weighings became less than 1% of the original mass.

Grinding: Waste material contained ferrous and non-ferrous metals, plastic, etc. Plastic and polythene were hand-picked as they were not biodegradable and were supposed to interfere in the determination of carbon/nitrogen ratio. Metals were also removed by hand-picking. Now the dried sample was placed inside a mixer and was ground thoroughly till it passed through a sieve having a pore size of 0.45 mm.

Mixing: It was also accomplished by a mixer. The final mixing was achieved by transferring the material to a suitable container that was not more than half-filled by it. The container was closed tightly and the sample was allowed to mix for about one hour.

These three steps were followed for all 100 samples obtained in six batches of samplings in JNU campus and Munirka area. Composite samples were prepared separately for JNU and Munirka by mixing all ground samples collected during all four samplings. Once these three steps were over, the sample was considered to be ready for analysis of its various chemical constituents. The samples were analysed for the following:

a. pH
b. Organic matter
c. Carbon content
d. Potassium (K_2O)
e. Phosphorus (P_2O_5)
f. Nitrogen (N)

Analysis of chemical constituents and waste samples

Measurement of pH

pH of domestic waste is a measure of the extent of degradation, the waste has undergone. Normally, the pH of a fresh refuse is around 7, but on degradation, it tends to become acidic and so its pH goes down. However, a stabilized refuse has normally alkaline pH.

Reagent

1. Standard buffer of pH 7.0 and 4.0

2. Standard KCl (about 40 gms per 100 ml) for the bridge

Procedure:

1. The temperature setting was adjusted and a little KCl was passed from the junction followed by flushing with distilled water.
2. Then the standard buffer was placed in the electrode vessel and galss electrodes and calomel halfull with KCl junction were immersed in the buffer.
3. The instrument's dial was set at the known pH values of the standard buffer.
4. After a suitable lapse of 'warm up' time the instrument was balanced to eliminate the asymmetric potential. The buffer was then removed and the electrodes were carefully flushed off with water.
5. 10 gm. of the sample was placed inside a flask. 500 ml. of distilled water was added to this flask and the mixture was stirred for 5 minutes. Then the mixture was given 5 minutes to settle down and then the pH was measured using a pH meter with a glass electrode previously calibrated and corrected for temperature.
6. The glass electrode was moved about to ensure removal of the water film around the electrodes and the pH reading was again taken.
7. When the reading was constant, the value was recorded.

ORGANIC MATTER

Principle:

When a subatance is heated upto 600°C, its organic portion is oxidised into volatile oxidation products.

Procedure:

5 gm. of finely ground sample was placed in constant mass silica dish and heated in an electric furnace (muffle furnace) upto a temperature of 600°C for 2 hours. The dish was allowed to cool in a dessicator and weighed again.

Calculation:

The organic maker present in the waste sample was calculated as percentage of the original mass as follows:

ORGANIC MATTER =

(Initial Mass - Final Mass)/Initial Mass x 100

TOTAL ORGANIC CARBON

Carbon content of the domestic solid waste was determined by the empirical method. (New Zealand formulae)

Principle:

The ratio of organic matter to Carbon content remains constant at 1.724 in case of solid waste.

Procedure:

Organic matter is determined as described above and then the carbon content is calculated as follows:

Carbon, percent = Organic matter, percent/1.724

TOTAL POTASSIUM (K_2O)

Principle:

Solid waste containing organic matter is decomposed by treatment with sulphuric-nitric acid mixture. Ashing is done to convert to their respective sulphates and the residue is treated further with acid mixture containing HF to make it silica free. Sample is then subjected to flame photometric analysis.

Reagents:

1. Acid mixture - 100 ml 1:1 H_2SO_4 + 650 ml. of conc. HNO3 + 250 ml. of distilled water.
2. Nitric acid - 5.1%
3. HF - 40% (m/m)
4. H_2O2

Procedure:

1. 1 gm. of sample was taken and treated with 5 ml. of concentrated sulphuric acid and 5 ml of conc. nitric acid. Mixture was heated till the brown fume ceased to come. Again 5 ml. of conc. HNO_3 was added. Again it was heated till the brown fume ceased to come. Then it was cooled. Now 10 ml. of hydrogen Peroxide was added and heated to fumes. Now the remaining material was ignited at 600°C for almost one hour till all the carbonaceous matter burnt off.

2. Now the ashed residue was treated with 10 ml. of acid mixture and 10 ml. of HF in a Platinum dish and heated to dryness. Addition of acid mixture and HF was repeated. Again it was heated to dryness on a water bath and then cooled. 50 ml. of 5% HNO_3 was added again and heated to dryness in a water bath and the volume was made upto 250 ml.

3. A flame photometer was used to measure the potassium concentration of waste sample. The potassium filter was selected. The gas pressure slit width and other settings were adjusted as required. The instrument was calibrated with standard potassium solutions of different concentration. Now an aliquot of the above-prepared sample solution was subjected to the instrument and its concentration was noted down.

Calculation:-

Potassium (as K_2O)
% by mass =

$$\frac{\text{conc. of K measured in the aliquot of the solu. X volume of the original solution}}{\text{1000 X weight of the solid waste sample}}$$

where

conc. of K is in gm/litre, volume in ml and weight of the solid waste sample is in gms.

TOTAL NITROGEN (N)

Following method was used for determining the total nitrogen (ammoniacal, organic and nitrate) of urban refuse, compose, etc.

Reagents:

1. Sucrose
2. Chromium Metal
3. Hydrochloric acid (conc.)
4. Potassium Sulphate
5. Mercuric oxide
6. Sulphuric acid (conc.) - 95-98%
7. Zinc metal (granulated)
8. Alkaline thiosulphate solution - About 450 gm. sodium thiosulphate was dissolved in approx. 700 ml. waster, cooled and 32 gm. Sodium thiosulphate was added

and diluted with water to one litre.

9. Boric acid - 4%

10. Mixed indicator - 10 ml. of 0.1.1 bromoeresol green in 95% alcohol was mixed with 2 ml. of 0.1% methyl red in 95% alcohol. The color produced by this indicator in boric acid in bluish purple with a trace of ammonia the color becomes bluish green. One drop in excess of acid turns the color of the solution to pink.

11. Sulphuric acid - 0.1N

12. Alumdun

Procedure :

About 5 gm. of prepared solid sample was weighed. (A blank was also run by weighing 2 gm. of sucrose). Samples were transferred to 500 ml. kjeldahl flask. To each flask 1.2 gm. of chromium and 35 ml distilled water was added and were kept swirling for 10 minutes. 7 ml. concentration hydrochloric acid was added to each flask. They are left for some time to facilitate color development. Each flask was heated on burner for 5 minutes. Then they were cooled and 22 gm potassium sulfate, 1 g mercuric oxide and 1.5 g aladin was added to each sample. 25 ml concentration sulphuric acid was added to each flask. Then they were heated for 2 hours. When the digestion mixture becomes whitish yellow, it is allowed to cool. Water was added and mixture was transferred to 200 ml volumetric flask and made upto 200 ml. 100 ml of it was transferred to nitrogen distillation assembly and was provided for distillation as given below.

Digestion:

100 ml of the solution was taken to a kjeldahl assembly. Alkaline thiosulfate solution was added to make it highly alkaline. 0.5 g of zinc dust was added. About 150 ml of distillate was collected in a Erlenmeyer flask containing 50 ml of 4% boric acid and a drop of mixed indicator. This distillate was titrated with 0.N sulphuric acid.

Calculation:

Total nitrogen was calculated as percentage of the original mass as follows:

Nitrogen (as N), % by mass = [(A - B) x N x 14 x 100 x 2]/E

where,

A = 0.1 N sulphuric acid used in the titration of the solid waste sample, ml, and

B = 0.1N sulphuric used in the titration blank, ml;

N = Normality of standard sulphuric acid; and

E = mass in gm of the solid waste sample

PHOSPHORUS (P_2O_5)

Phosphorus was estimated by the Quinoline phosphomolybdate method.

Reagents

1. Quinoline Hydrochloric acid solution - 20 ml of purified quinoline was added to 500 ml of hot water acidified with 25 ml of conc. H_2SO_4 cooled and diluted.
2. Citro-molybdate reagent -

a) Dissolved 150 gm of sodium molybdate in 400 ml of water.

b) Dissolved 250 gm of citric acid in 250 to 300 ml of water and 280 ml of conc. HCl. Poured with stirring, solution (a) to (b), cooled and filtered through a filter pad. A slight greenish color develops on mixing which deepens when exposed to sunlight. Added in drops, a 0.5% (m/v) solution of potassium bromate to discharge the colour.

3. Mixed indicator solution - mixed 3 volumes of alcoholic phenol phthalein solution and 1 volume of alcoholic thymol blue solution.
4. Standard sodium hydroxide solution - carbonate free 0.5N and 0.1N.
5. Standard hydrochloric acid - 0.5N and 0.1N
6. Dilute HCl - 10%

Procedure

In a conical flask (250 ml) an aliquot of the clear solution of the material was taken, containing about 50 mg of phosphorus pentoxide present as orthophosphate in about 100 ml. 50 ml of citromolybdate reagent was added and boiled. 5 drops of quinoline hydrochloride solution was added with stirring. Again it was boiled and quinoline hydrochloride was added slowly upto 60 ml. A coarsely crystalline precipitate is formed. Then it was cooled and filtered through a filter paper. Flask, precipitate and filter were washed with cold water till they were acid free. The filter pad and the precipitate were transferred to the original flask and funnel was rinsed with water into the flask. It was diluted with water upto 100 ml. Now the flask was shaken vigorously to disintegrate the precipitate and the paper. From a burette, 50 ml. of 0.5 N standard NaOH solution was added while shaking the flask. Flask was shaken so that all precipitate got dissolved. 1 ml. of mixed indicator solution was added and the excess of NaOH was titrated with 0.5N HCl till the indicator changes from violet to green blue and then very sharply to yellow.

Similar experiment was done with the blank using all reagents without the sample and by using 0.1N standard NaOH solution and 0.1N HCl instead of 0.5N acid and 0.5N alkali.

CALCULATION

Phosphates (as P_2O_5), $= 0.1366 [V_1 - V_2 - \{V_3 - V_4\}/5] / M$
Percent by mass

where

V_1 = volume in ml of 0.5N NaOH solution used with sample
V_2 = volume in ml of 0.5N HCl used with the sample
V_3 = volume in ml of 0.1N HCl used in the blank, and
V_4 = Mass in gm of the material contained in the solution taken for the precipitation.

CHAPTER 6

RESULTS AND DISCUSSIONS

Various samples from JNU and Munirka were analysed for different physical and chemical parameters. The detailed results of the various experiments performed with these samples are being given here and simultaneously a discussion of these results is also being presented.

Characteristics of six residential sectors

Table 1 shows the physical characteristics of wastes of different residential sectors within JNU and Munirka areas. Here the results of sampling regarding total waste generation, number of persons surveyed, density and volume during each sampling have been presented. This is basically a primary data on the basis of which a comprehensive analysis of these data has been done and presented in table 2. This table shows the average number of persons surveyed, average volume per head per day, average waste generation per head per day, average density, range of densities, average waste generation per house per day and average volume per house per day in each residential sector. It also shows average values of these parameters in JNU and Munirka area and also the average value of these two areas.

Table 1. Characteristics of six residential sectors

Sampling area & number	Total waste generated (gms)	No. of persons surveyed	Density (gm/lit)	Volume (litre)
B & C Quarters				
1	1546	21	371	4.2
2	1377	25	432	3.0
3	1276	21	321	3.78
4	1259	22	390	3.3
Uttarkhand				
1	1121	17	412	2.72
2	835	14	309	2.8
3	1078	16	394	2.72
4	1262	16	297	4.16
Dakshinapuram				
1	967	11	349	2.75
2	983	14	242	3.36
3	1189	15	486	2.4
4	1069	16	290	3.68
Poorvanchal				
1	1081	17	344	3.06
2	1029	15	310	3.3
3	1102	17	266	4.08
4	1195	17	212	5.61
Munirka village				
1	1284	25	461	2.75
2	1342	23	391	3.45
DDA Flats				
1	1751	20	337	5.2
2	1753	19	293	5.89

Results of domestic solid waste generation survey

(i) Comparison among residential sectors

It is quite clear from table 2 that the average number of persons her house is greatest in Munirka village and lowest in Dakshinapuram sector of JNU campus. This shows that with increase in per capita income, number of persons in each house decreases. This happens because of the increase in education and awareness among people which is closely associated with the income growth. Average volume per head and per house per day of the domestic waste generated are highest in DDA flats, while per head and house lowest in Munirka village and Uttarakhand respectively. Similarly, the average waste weights/(house and head)/day are also highest and lowest in DDA and Munirka village respectively. Density variation was found to be greatest in Dakshinapuram area while the highest and lowest average densities were reported from Munirka village and Poorvanchal area respectively.

(ii) Comparison between JNU and Munirka

Average values of all parameters from the four residential sectors in JNU campus and two residential segments from Munirka were taken for arriving at the average values of JNU and Munirka area respectively.

Analysis of the data in table 2 shows a lesser value of average vol./head/day in Munirka, while other parameters such as, no. of persons/house, avg.vol./house/day,

Table 2 Results of domestic solid waste generation survey

Residential sector	Av. no. of persons per house	Avg. vol/ head/day (litre)	Avg. vol/ house/ day(litre)	Avg. wt/ head/ day (gms)	Avg wt/ house/ day (gms)	Avg density (gm/l)	Range of densities (gm/lit)
B & C Quarters	4.45	0.16	0.7	61.65	272.9	378.5	329-432
Uttarakhand	3.15	0.19	0.61	67.95	214.8	353.0	297-412
Dakshinapuram	2.8	0.23	0.64	76.04	210.4	341.75	242-486
Poorvanchal	3.3	0.24	0.81	66.82	220.35	283.0	212-344
Munirka village	4.8	0.13	0.62	54.85	262.6	426.0	391-467
DDA Flats	4.35	0.28	1.10	89.90	350.4	315.0	293-337
JNU	3.42	0.20	0.69	68.11	229.61	339.06	212-486
Munirka	4.35	0.16	0.86	72.37	306.5	370.5	393-461
Avg of JNU/Munirka	3.9	0.18	0.77	70.24	268.05	354.78	212-486

avg.wt/head/day, avg. density and avg.wt/house/day are higher compared to the JNU campus. A close scrutiny of these results reveals that the JNU campus generates waste of lower density value with higher avg.vol./head. We will understand its reason if we look at the table 5, which shows that while vegetable and other compostable matter percentage in higher in Munirka, percentage of paper, metal, textiles and plastics is lower compared to the JNU campus. This results in higher volume occupation per litre by wastes from the JNU campus compared to the one from Munirka. Though the avg.wt./head in quite comparable in these two areas, avg.wt./house is quite high in Munirka because of the fact that the no. of persons per house is greater compared to that of JNU.

Physical Characterisation of Domestic Solid Wastes

Domestic waste samples of the four residential sectors in the JNU campus and two residential sectors in Munirka have been studied for their physical characterisation. Five parameters have been studied, namely, vegetables and other food wastes, papers, plastics (including rubber), textiles and metal.

Table 3(i) shows the percentage and amount of each of the waste constituents at each sampling in all six residential segments of JNU and Munirka areas. Since the samples were taken in January, February, April-May and July in both JNU and Munirka areas, this table also gives us an idea about the seasonal variation in waste constituents in each of the six residential sectors. However this is basically again a primary data based on which various calculations have been done to arrive at different conclusions depending on different requirements.

(i) Comparison among residential sectors

Table 4 describes the average values and percentage weights of each of the waste constituents per house in different residential sectors of both JNU and Munirka areas.

From the table, it is quite clear that the vegetable and other food waste amount generation is highest in DDA flats and lowest in Dakshinapuram. However the percentage weight of vegetable and other food waste is highest in Munirka village and lowest in Dakshinapuram. This is quite expected as it is a well known fact that with growth in income organics and other putrescible matters tend to become low in the waste. As expected, data from Uttarakhand, Dakshinapuram and Poorvanchal shows quite comparable results.

Paper generation per house is highest in DDA flats and lowest in Munirka village. Uttarakhand has the highest percentage of paper among all residential sectors while the lowest percentage weight is found in munirka waste. Here again, it can be safely inferred that in the area with lower income houses, paper percentage is lesser compared to the higher income areas.

Table 4 Average values and percentages of different waste constituents per house (Unbracketed values in gms) (Values in parentheses in percentage)

	Vegetables	Paper	Plastics	Textile	Metal
B & C Quarters	246.55 (90.17)	9.9 (3.62)	13.3 (4.86)	2.05 (0.75)	1.60 (0.58)
Uttara-khand	184.7 (86.47)	11.05 (5.17)	13.9 (6.5)	2.1 (0.98)	1.85 (0.86)
Dakshina-puram	182.1 (86.19)	10.55 (5.02)	13.3 (6.33)	2.7 (1.28)	2.45 (1.17)
Poorvan-chal	192.3 (87.27)	9.95 (4.51)	14.45 (6.55)	1.45 (0.66)	2.2 (0.99)
Munirka village	241.0 (91.94)	8.1 (3.050	8.0 (3.05)	1.9 (0.72)	3.1 (1.18)
DDA Flats	318.0 (90.88)	14.5 (4.14)	13.2 3.77)	1.8 (0.51)	2.4 (0.68)
JNU	201.16 (87.7)	10.36 4.52)	13.73 (5.98)	2.07 (9.040	2.02 (8.83)
Munirka	279.5 (91.34)	11.3 (3.69)	10.6 (3.46)	1.84 (0.60	2.74 (11.89)

Three of the four sectors in JNU campus, representing higher income-group housing show similar percentage of plastics in their wastes. As expected, B&C Quarters and Munirka village have the lowest value of plastics in their wastes.

Textiles and Metals are generated in very low amounts and their percentage weight in wastes is also very low. However, in general the high income areas show a comparatively higher percentage of these two constituents in their waste.

From above discussion, it becomes quite clear that residential sectors with high income-group residents exhibit a higher amount and percentage weight per house of each of these wastes constituents compared to the middle income areas (B&C Quarters and Munirka village). This is true as the use of paper, polythene bags, rubber, plastics, textiles and metallic goods increases with the increase in the income of people. As a result, percentage of vegetables and other putrescible matter in the waste goes down.

(ii) Comparison between JNU and Munirka areas

Table 5 shows a comparison between JNU and Munirka areas in relation to the above mentioned waste constituents.

Comparison of the data reveals that the percentage weight of vegetable and other food waste is higher in Munirka while rest other constituents occupy lower percentage.

Table 5 Percentage weight of waste constituents (JNU-Munirka)
(All values in percentage)

	Vegetables	Paper	Plastics	Textile	Metal
JNU	87.69	4.55	5.99	0.88	0.88
Munirka	91.33	3.69	3.46	0.6	0.89
Average	89.51	4.12	4.72	0.74	0.88

Percentage of metal is quite comparable.

Generally speaking, the refuse from both areas show a high compostable and low combustible matter in their domestic wastes. Since JNU campus houses higher-income residents in much more proportion compared to Munirka area, the above found result seems quite compatible for the reason discussed earlier in this chapter.

Comparison of waste constituent per head per day

Table 6 shows a comparison of different waste constituents generated in six residential segments of JNU and Munirka areas.

(i) Comparison among different sectors

An analysis of the table shows that the per capita generation of vegetable matter, paper, textiles and metals is higher in high-income group areas. DDA flats show high values of all parameters in their wastes while Munirka village shows their lowest percentage weights. One striking feature is the almost equal per capital generation of plastics in the wastes of all sectors. This is because of the fact that the use of plastics, polythene bags, etc. is becoming common at all income levels.

Table 6 Waste constituents / head / day
(All values in gms)

	Vegetables	Paper	Plastics	Textiles	Metal
B & C Quarters	55.4	2.22	4.45	0.46	0.36
Uttara-khand	58.63	3.54	4.41	0.67	0.58
Dakshina-puram	64.64	3.76	4.75	0.96	0.87
Poorvan-chal	58.27	3.01	4.38	0.44	0.67
Munirka village	50.2	1.68	1.67	0.39	0.64
DDA Flats	73.1	3.33	3.03	0.41	0.55
JNU	58.81	3.03	4.01	0.63	0.59
Munirka	64.25	2.59	2.43	0.42	0.63

(ii) Comparison between JNU and Munirka

Comparison shows that the per capital weight generation of paper, plastics and textiles is more in JNU campus compared to Munirka. But Munirka has higher vegetable matter generation rate.

Seasonal variation in waste constituents

Table 3(i) shows the amount and percentage of different waste constituents collected during each sampling in all sectors. Since these samplings were taken in January, February, April-May and July in JNU and Munirka areas, this table gives us the opportunity to study the variations in waste constituents seasonally within and among residential sectors.

(a) Variation within residential sectors [Table 3 (i)]

(1) B&C Quarters - Comparison within this area shows highest percentage of vegetable in the summer, paper in spring, polythene and textiles in the rainy season and an equal percentage of metal in all except summer..

(2) Uttarakhand - Here the vegetable percentage is greatest in Spring, paper in Winter, plastics and textiles in the rainy season and again about equal metal

Table 3(i) Seasonal variation in waste constituents in 6 residential sectors (Unbracketed values in gms) (Values in parentheses in percentage)

Sampling area & number	Vegetables	Paper	Plastics	Textiles	Metal
B & C Quarters					
1	1425 (92.17)	39	69	8 (0.51)	5 (0.32)
2	1281 (88.75)	48	8	18 (1.29)	9 (0.64)
3	1135 (88.94)	57	70	5 (0.39)	9 (0.7)
4	1140 (90.54)	54	46	10 (0.79)	9 (0.71)
Uttarakhand					
1	955 (85.19)	58	90	9 (0.8)	9 (0.8)
2	694 (82.13)	43	80	8 (0.94)	10 (1.18)
3	915 (86.32)	56	64	15 (1.41)	10 (0.94)
4	1130 (89.54)	64	44	16 (1.26)	8 (0.63)
Dakshinapuram					
1	820 (85.32)	40	75	16 (1.64)	10 (1.04)
2	822 (83.45)	47	81	16 (1.62)	19 (1.92)
3	1045 (87.30)	54	62	13 (1.08)	13 (1.08)
4	935 (87.46)	70	48	9 (0.84)	7 (0.65)
Poorvanchal					
1	944 (87.32)	55	69	5 (0.46)	8 (0.74)
2	857 (83.28)	50	99	7 (0.68)	16 (1.55)
3	965 (88.37)	48	71	13 (1.19)	5 (0.45)
4	1080 (89.62)	46	50	4 (0.33)	15 (1.24)
Munirka village					
1	1185 (92.28)	38	41	9 (0.7)	11 (0.85)
2	1225 (91.62)	43	39	10 (0.74)	20 (1.49)
DDA Flats					
1	1580 (90.49)	72 (4.12)	65 (3.72)	10 (0.57)	19 (1.09)
2	1600 (91.27)	73 (4.16)	67 (3.82)	8 (0.95)	5 (0.28)

1 - April-May (summer) 2 - July (rainy season)
3 - January (winter) 4 - February (spring)

percentage in all seasons.

(3) Dakshinapuram - Here the vegetable percentage is the highest in Spring, paper in spring, metals, polythene and textiles again in the rainy season.

(4) Poorvanchal - Here the vegetable and paper percentage are greatest in summer, metals and polythene in the rainy season and textiles in winter. Not much variation was found in Munirka village and DDA flats as the interval between sampling was quite short.

Seasonal variation within JNU [Table 3(ii)]

Here we find the highest percentage of vegetable matter in spring and summer, paper in winter, plastic, textile and metals in the rainy season.

Highest percentage of vegetable matter is quite expected during summer and spring probably due to more availability of vegetables in this season at cheaper rate and consequently more likelihood of consumption by all people. The reason for paper being found most in spring is unknown. Probably, because of widespread use of plastics as polythene bags, plastic sandles, textiles, etc., in rainy season, their percentage becomes greater in wastes this time. However, the reason for high metal percentage during rainy season is unknown, though in all seasons, they occupy similar percentage weight.

Table 3(ii) Seasonal variation in JNU (Unbracketed values in gms) (Values in parentheses in percentage)

Sampling Number	Vegetables	Paper	Plastics	Textile	Metal
1	4144 (88)	192 (4.07)	303 (6.43)	38 (0.8)	32 (0.68)
2	3604 (85.08)	188 (4.43)	341 (8.05)	49 (1.15)	54 (0.27)
3	4060 (88.64)	215 (4.69)	267 (5.83)	46 (1.0)	37 (0.8)
4	4285 (89.55)	234 (4.89)	188 (3.93)	39 (0.81)	39 (0.81)
Seasonal variation in Munirka					
1	2765 (91.25)	110 (3.63)	106 (3.49)	19 (0.62)	30 (0.99)
2	2825 (91.42)	116 (3.75)	106 (3.43)	18 (0.58)	25 (0.8)

1 - April-May (summer)   2 - July (rainy season)
3 - January (winter)   4 - February (spring)

Patterns of domestic refuse quantities and characteristics of middle and higher income areas within JNU-Munirka area

Table 7 shows a comparison of domestic waste quantities and characteristics for middle and higher income areas. Here the middle income area is represented by B & C quarters and Munirka village, while the rest three sectors in JNU campus and DDA flats represent high income areas.

Several conclusions can be drawn from this table. The refuse from middle income areas vary with that of higher income areas in that:

(a) waste generation rate is low, generally one and a half times lower,

(b) waste densities are high, generally 1.3 times,

(c) vegetable and other food waste is high,

(d) paper, metal and textile content is low

Above results are quite compatible with the view that with increase income, except vegetable matter, composition of other constituents tend to increase.

Table 7 Patterns of domestic refuse quantities and characteristics of middle and high income areas within JNU-Munirka

	Income group	
	Middle	High
Waste generation (gm/head/day)	54.85-61.65	66.82-89.9
Waste densities (wet wt.basis - gm/l)	378.5-426	283-353
Comparison (% by wet wt.) - Vegetables and other food waste	90.17-91.94	86.19-90.88
Paper	3.09-3.62	4.14-5.17
Plastics	3.05-4.86	3.71-6.55
Textiles	0.72-0.75	0.51-1.28
Metal	0.58-1.18	0.68-1.18

RESULTS : CHEMICAL ANALYSIS

Chemical analyses were performed on the domestic solid waste samples of the six residential sectors for obtaining values of various chemical parameters.

Comparison of chemical characters of wastes from six residential sectors of JNU-Munirka area

Table 8 shows the values of different chemical parameters obtained for each of the six residential sectors. Importance of these chemical parameters together with their variations within these segments, is being discussed here:

1. Moisture Content :

Moisture content of the domestic waste determines to a large extent, the suitability of the waste for a particular disposal method. Wastes with more than 50% of moisture content, are not suitable for incineration and hence sanitary landfill should be considered. Incinerating wastes with high moisture content needs a large amount of auxialiary fuel which makes incineration a highly uneconomical disposal practice in this case.

It becomes quite clear from the table that the domestic waste from Munirka Village has the highest moisture percentage in it followed closely by wastes from DDA flats and B&C Quarters. Wastes from the rest three areas with almost similar values, contain lesser amount of moisture. Since vegetable materials have the highest moisture content among all physical parameters, its percentage value in the domestic waste decides the moisture content of the waste to a large extent. For this reason, Munirka Village with the highest percentage of vegetable materials in its waste, has also the highest moisture content in its waste. As the vegetable percentage of the waste goes down, its moisture content also decreases and hence we observe lower values of moisture percentage in wastes from Poorvanchal, Uttarakhand Dakshinapurum.

2. Organic Matter :

The organic content of the refuse indicates the amount of compost that could be produced from it. As organic matter content in wastes from all residential areas is very high, these wastes are expected to yield good amount of compost.

Munirka Village has the highest organic matter percentage in its waste whereas Poorvanchal has the lowest value. Thus the organic matter content of the domestic refuse decreases with the increase in the income-level of the people and hence areas with relatively high income-level, such as, Poorvanchal, Uttarakhand and Dakshinapurum show relatively lower organic matter in their wastes.

3. Total Organic Carbon :

Since the total organic carbon content of the refuse in almost directly proportional to the organic matter content of the refuse, its variation among wastes of different residential areas follows the similar pattern as observed in case of organic matter.

4. Nitrogen, Phosphorus and Potassium :

These three elements are the most essential nutrients for proper plant development and hence the refuse with a high percentage of these nutrients is considered very good for composting.

Nitrogen (N), Phosphorus (P2O5) and Potassium (K2O) contents of the domestic solid refuse tend to decrease with the decrease in the vegetable matter content of the refuse. This is why Poorvanchal, Uttarakhand and Dakshinapurum with lower vegetable matter content in their wastes have lower values of these three nutrients compared to the high vegetable matter containing domestic refuse of Munirka Village and B&C Quarters. As a result, compost formed out of domestic wastes generated in these areas will contain less amount of N, P & K nutrients.

5. pH

pH value of a refuse indicates whether that particular refuse is acidic, neutral or alkaline. A low pH value indicates a slightly acidic nature of wastes from all areas. As food and other biodegradable wastes degrade, acid is formed which lowers the pH value of the refuse making it acidic. Since by the time domestic waste samples were collected some degradation had already taken place and this imparted an acidic nature to the waste. However, a fresh refuse has a pH value around 7 which indicates a neutral character.

6. C/N ratio :

C/N ratio is the most important factor in the determination of the suitability of the refuse for composting. Since living organisms utilise about 30 parts of urban for each part of nitrogen, an initial C/N of 30 would be most favourable for rapid composting. C/N ratio in the domestic refuse increases with the increase in the income-level of an area and for this reason Dakshinapurum has the highest C/N ratio whereas B&C Quarters has the lowest value of C/N among all residential sectors. Usually, with increasing urbanisation, suitability of the refuse for composting tends to go down.

Comparison of Chemical Characters of Wastes from JNU & Munirka areas

Chemical analyses were performed on the composite waste samples of JNU and Munirka areas. Already prepared waste samples from Uttarakhand, Poorvanchal, Dakshinapurum and B&C Quarters were mixed thoroughly to get a composite sample for JNU, while samples from Munirka Village and DDA flats were mixed to get a composite sample for Munirka area.

Analysis of the table 8 illustrates that the moisture content is higher in the Munirka waste compared to the one from JNU. As we find the percentage of vegetable materials greater in the Munirka waste, greater valuc of the moisture content is quite expected. The reason for this has already been discussed. Organic matter share in the domestic refuse is greater in case of Munirka. This is also in conformity with the well established fact that with the increase in the income-level the organic matter content of the waste decreases. Carbon, as expected, occupies greater proportion in the Munirka refuse. Values of Nitrogen (N), Phosphorus (P_2O_5) and Potassium (K_2O) are higher in case of Munirka waste. As the share of vegetable materials goes down in the domestic solid refuse, values of these three nutrients also go down and hence we have lower percentage of them in the JNU refuse. pH shows a higher value in case of JNU waste. Since the vegetable matter percentage is lesser JNU waste, less degradation is there which results in a lesser pH value.

Table 8

Chemical characteristics of domestic solid wastes of six residential sectors

(values in percentage except for pH and C/N ratio)

Residential Sectors	pH	Moisture Content	Organic Matter	Carbon as (Total organic)	Prosphorus as (P_2O_5)	Nitrogen as (N)	Potassium as (K_2O)	C/N Ratio
Uttarakhand	6.61	63.47	71.80	41.64	0.62	0.60	0.69	70.40
Poorvanchal	6.93	63.53	69.90	40.54	0.67	0.56	0.62	73.42
Dakshinapurum	6.65	63.41	74.73	43.34	0.59	0.54	0.63	81.40
B & C Quarters	6.52	66.82	76.36	44.29	0.73	0.64	0.78	70.18
Munirka village	6.47	67.04	77.92	45.19	0.76	0.62	0.72	73.93
DDA Flats	6.13	66.92	74.83	43.40	0.69	0.58	0.71	75.89
JNU	6.72	64.31	73.62	42.70	0.64	0.57	0.67	75.96
Munirka	6.34	66.98	76.49	44.36	0.73	0.60	0.71	74.98

CHAPTER 7

FUTURE TRENDS IN DOMESTIC WASTE GENERATION

While planning a processing or disposal facility as well as the total solid waste management, forecasting the future load and composition becomes necessary. However, no previous data is available regarding domestic waste in India including our study sites of JNU and Munirka areas. This makes the task of predicting the change in domestic waste composition in future years very difficult. In absence of any historical data, it would be necessary to rely on the recognised trends in municipal refuse data observed in other places and countres.

Table 9 gives some of the physical characteristics of refuse from Pune (India) as observed during 1970 and 1978. As the corresponding quantities of rags, glass, metals, plastics, etc., increased in 1978, the proportion of compostable material decreased.

Similarly, Table 10 gives the physical characteristics of refuse from U.S.A. obtained during 1970 and 1987. A comparison of these two data would reveal that the contents of metals, glass, leather, rubber and plastics have gone up while compostable matter percentage has gone down.

Thus a clear trend in the variation of refuse characters with time can be seen at

Table 9 Changes in physical characteristics of city refuse in Pune, India (All values in percentage)

Characteristics	Years 1970	1978
Compostable material	67.0	60.66
Paper	8.74	7.0
Glass	0.58	0.67
Rags	1.63	4.21
Plastics	0.72	0.89
Metals	0.59	0.77

Table 10 Changes in physical characteristics of refuse in USA
(All values in percentage)

Characteristics	Years 1970	1987
Food wastes	20.0	8.1
Paper	37.4	37.1
Glass	9.0	9.7
Textiles	2.2	2.1
Metal	8.4	9.6
Plastics	1.4	7.2
Leather and rubber	1.2	2.5

both places and that is with the increase in the contents of plastics, metals, glass, rubber and leather, etc., the percentage of compostable material goes down.

We can expect this trend in JNU and Munirka area, too, as with the increase in prosperity and westernisation, this area is also bound to follow the consumption pattern of richer countries.

In general, it can be said that the paper, cardboard and other wood-fibre products will comprise an increasingly dominant fraction of the refuse. This change will decrease bulk density, adversely affecting almost all collection, storage and handling operations associated with disposal facilities.

Metal content in the refuse is also expected to go up. Though its use will grow at a significant rate, its percentage in the refuse is not expected to grow at the same rate as most of it will be retained in the households either for reuse or for selling to hawkers for some income.

Plastics are the category showing maximum growth rate in refuse almost everywhere. This is due to the ever increasing use of this material in the households. In India, use of plastics is gathering momentum and it is fast replacing metals and papers for different uses because of its non-corrosive character, light weight and cheaper price. However, this is a point to worry as it is non-biodegradable and hence causes problems during disposal. Incineration of plastics also causes emission of harmful gases. In particular, the fraction of PVC in the plastics waste is expected to increase greatly leading to many times increase in potential hydrochloric acid emissions in the coming years.

Although the percentage of textiles in American refuse has shown a steady state, the same can not be expected from the refuse of JNU and Munirka area as with growth in income level, it is also bound to grow.

As is the case everywhere, the content of food wastes in our study area will decline. However not much change can be foreseen as it occupies a predominant position in the refuse of this area. The steady decline in the food-waste content will reduce the compostability of refuse and the fertilizer value (nitrogen, phosphorus and potassium) of the resulting compost.

Moisture content is also expected to go down with the decrease in food-wastes fractions in refuse. This will shift the presently favoured disposal system of sanitary landfill and composting towards incineration.

SUMMARY

Present study reveals that the average number of persons per house is greater in Munirka compared to the JNU area which generates a greater average volume of domestic solid wastes per head, while a slightly higher volume of domestic solid wastes per house in generated in Munirka. Average weight per head and house of domestic solid wastes is greater in case of Munirka. Munirka waste also shows a higher average denisty compared to the JNU refuse.

We also observe that the per capita consumption of vegetable matter is slightly higher in Munirka compared to the JNU area. However, other waste constituents, such as, paper, plastics and textiles are consumed more by a person in the JNU complex than in Munirka.

^{P}H values of most of the domestic solid waste samples from both the places tend to show slight acidic in nature, while fresh samples from the JNU area have shown neutral ^{P}H values. ^{P}H values of JNU samples have slightly higher value compared to those of Munirka. Moisture content of the samples is higher in case of Munirka waste. Total organic carbon percentage in Munirka sample shows a slightly higher value. We also observe higher percentage of N,P&K nutrients in the Munirka waste. C/N ratio is slightly higher in case of JNU waste as compared to Munirka, with the increase in the income-level of the community, C/N ratio of domestic wastes generated has been found to increase. This trend has also been noticed in this study. Apart from the income-level of the different groups of residents, socio-cultural habits of the population will also influence the nature of domestic solid wastes generated.

As present, in Munirka Village, domestic solid waste is dumped as heaps in open spaces leading to unhygienic conditions in these areas. Simple, satisfactory transfer facilities should be built with a split-level format to facilitate loading of the vehicles, and a wall around three sides to maintain hygienic conditions as well as the aesthetic value of the neighbourhood. This will certainly improve the sanitary conditions of these areas.

Domestic solid wastes generated from JNU-Munirka area might be utilised effectively through proper arrangement of composting. Thus there remains a great scope of further work in this line for future days.

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