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ORANGI - KARACHI
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SOLID WASTE MANAGEMENT IN ORANGI

PROJECT REPORT

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NOVEMBER, 1984

343-1411-2

SOLID WASTE MANAGEMENT IN ORANGI

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LIST OF ACRONYMS

BCCI	Bank of Credit and Commerce International
CDP	Community Development Project
KDA	Karachi Development Authority
KMC	Karachi Metropolitan Corporation
PCSIR	Pakistan Council For Scientific and Industrial Research

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1.0 INTRODUCTION

1.1 General

This report results from a study of refuse disposal practices in Orangi. The study conducted during September and October, 1984 sought to identify disposal mechanisms within the community and assess the efficacy of the disposal service currently available. Investigations were also conducted to determine the quantity and characteristics of the Orangi refuse and establish alternate methods of refuse collection and processing and ascertain the potential for resource recovery. Incorporated in the report are alternate proposals for setting up a comprehensive refuse collection and disposal service for the project area.

1.2 The Purpose of the Study

The objective of the present study is to review current refuse collection and disposal services and to present proposals for improvement to the present system to establish a unified and comprehensive service of refuse collection, disposal and street cleansing for Orangi. Set within the framework of this prime objective are the following detailed objectives.

1. To review town planning and development proposals and to establish population densities and distribution within the project area.

2. To assess current, and predict future, volumes of refuse generation and content for assessment of basic design parameters.

3. To define collection areas and establish alternate collection methods suited to the needs of the project area.

4. To identify and test appropriate methods of refuse treatment and disposal having regard for economic and environmental factors.

5. To outline the likely manpower requirements for the alternate services and suggest suitable plant and vehicles to operate these services.

1.3 Acknowledgements

Much of the analyses undertaken to determine the physical and chemical composition of Orangi refuse, and all work related to the development of appropriate means of composting the refuse, were conducted in the laboratories of the Pakistan Council for Scientific and Industrial Research (PCSIR) - Karachi. Appreciation is expressed to the institution's Director Dr. M. A. Beg for his support and for making the facilities available. The dedicated cooperation of Miss Radia Noorani, Senior Research Officer, and Mrs. Naseem Usmani, Research Officer, in executing and monitoring the work on composting and performing all necessary physical, chemical and bacteriological analyses, is most gratefully acknowledged. The assistance of Mr. Subhan Beg, Technician, in determining the physical composition of the refuse analysed is also acknowledged.

2.0 THE STUDY AREA AND POPULATION

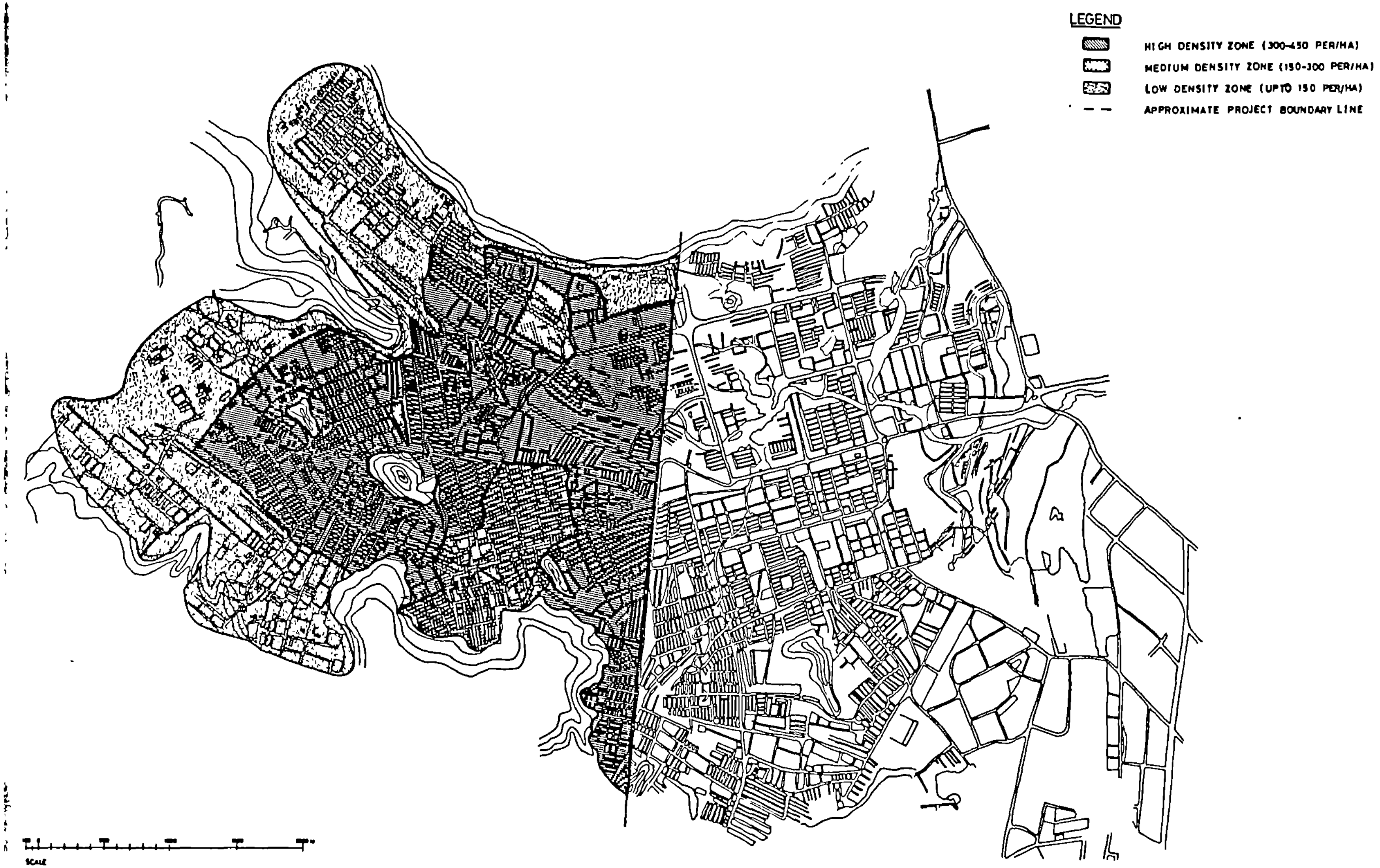
2.1 The Study Area

2.1.1 General

Orangi, the largest "Katchi Abadi" (Squatter Settlement) in Karachi is located at the north-west fringe of the city approximately 12km from its centre. Situated in a semi desert valley bound to the north and south by hill ranges, which serve as a natural boundary to the settlement, the study area has a variable topography with elevation between 54 and 93m above sea level. Orangi is surrounded by the Hub Valley in the North, Qasba and Baldia to the East and West respectively, and the Sind Industrial Trading Estate (SITE) to the south which absorbs a majority of the Orangi workforce.

During 1967, KDA designed a plot development scheme for 540 hectares which was sub-divided into 14 sectors, aimed at providing housing to the low-income groups. This formed the initial phase of a full scheme to be planned subsequently. However, following events in the eastern wing of Pakistan in early 1970's, the vast tract of adjoining unutilized land, together with the planned sector, proved to be a haven for thousands of unfortunate migrants dislocated from former East Pakistan. Thus in approximately a decade Orangi grew into a township covering 2000 hectares. Subsequent immigration from rural areas north of the city has helped sustain its steady growth in population besides that resulting from natural increases. The proximity of the settlement to the industrial area of SITE and Shershah, offering opportunities for skilled and unskilled labour, the non-availability of affordable housing and the abundance of undeveloped vacant land acted as the major integrating forces behind the estabishment of the settlement.

1/ Much of the discussion presented herein is based on Ref: Directorate of Katchi Abadies, "Orangi - A Case Study", Karachi Metroplitan Corporation, Karachi, March, 1982.



BCCI-CDP	SOLID WASTE MANAGMENT IN ORANGI
	ZONAL DISTRIBUTION OF DESIGN POPULATIONS & DENSITIES
	SCALE: AS SHOWN | DATE: NOV. 1984 | DRG NO: 01

An estimated 600,000 people are settled in substandard conditions over the 2000 hectares. Of this, the present project has a target settlement area of 1000 hectares containing approximately 300,000 persons. While it is estimated that the population of the city is growing at an annual rate of 4.5 percent, the population in Orangi is predicted to grow at an annual rate of 7%, despite the low festility rate (below national average) registered in the area. The great number of building development activity in the area and the unrestrained expansion of the settlement proceeding further east, reaffirm the high population growth in the study area.

Despite the spontaneous, rapid rate at which the settlement was established, an inherent characteristic of Orangi, which distinguishes it from other "Katchi Abadies", is its regular planning pattern in much of its area. Other "Katchi Abadies" only possess vestiges of intentional planning. Although the largest of "Katchi Abadies", Orangi lacks the minimum of basic essential amenities and infrastructure. The Karachi Metroplitan Corporation (KMC) recently entrusted with the development of the area has provided some infrastructural services, but much remains to be done. The rapid rate of expansion has outstretched all services provided, of which sanitation and refuse disposal are perhaps the most wanting. Over half the area has neither access to electric nor gas supplies and a sparse network of inadequately maintained roads provide the only form of communication with the rest of Karachi.

2.1.2 Climatic Conditions 1/

Karachi has a moderate climate which occasionally becomes sultry due to intense humidity in the air. Mean annual temperature in Karachi is approximately 26.5 °c. May and June are the hottest months of the year with temperatures as high as 36°c, while January is the coldest with temperature

1/ Much of the data presented in this section is based on - Master Plan for Karachi Metropolitan Region, "Study of Climate Part-I", KDA, Karachi, March, 1971.

as low as 10°c. The humidity usually ranges between 58 to 85 percent during December to August with a mean annual value of about 75 percent. The city lies at the fringe of the monsoon belt and, hence, receives a low rainfall concentrated during July and August. Mean annual rainfall in the city amounts to 193mm, with a recorded maximum of approximately 600mm. Variations in rainfall from year to year is indeed large with a heavy storm return cycle of every 6 to 8 years. Intensities as high as 82mm per hour have been registered during these periods of heavy rainfall.

2.2 Population

2.2.1 General

An essential prerequisite to the formulation of proposals for refuse service requirements is the acquition of data relating to present population and to population growth. The former is a simple taks in this case as preliminary data is available from the census carried out in Mid 1982. The prediction of future population growth, however, is a notoriously difficult process in view of the many factors which may arise and which may have decisive effects. This is particularly true for squatter settlements since they are under constant threat of futher influx resulting from political situations similar to the one that was responsible for the initial creation of Orangi. Further, they are also dependent on governmental policies in relation to their disposition to regularize the settlement. The type and extent of population growth resulting from regularization and subsequent sustained development programmes are indeed difficult to predict. The picture is futher confounded by the inability to predict skilled and unskilled labour force requirements that the city, with the major port and the most important industrial and commercial centre of the country, is likely to demand in the near future.

Still more difficult is the problem of predicting the distribution of population. This distribution will undoubtedly be affected by the decisions which will be made during the regularization process and the landuse patterns defined therein.

2.2.2 Demographic Study

There is at present no demographic study available for Orangi which purports to esablish population projections and densities of settlement suitable for the immediate task. Preliminary total populations obtained from the 1982 census and field verified population densities of selected clusters 1/ and others obtained during the course of executing sanitation surveys in other areas were however available and formed the basis upon which population densities and projections have been defined in this document. Since no detailed demographic study was undertaken in developing these projections it would be prudent to verify and modify, if necessary, these parameters when more up-to-date information becomes available. The redefinition of these fundamental population parameters will undoubtedly require some corrections in the expected refuse quantities and their source distribution within the project area.

Although the present study is limited to the project area, it is unlikely that, in planning an urban service such as refuse disposal, this would be the optimum zonal size. The general findings of this report will, however, be valid and may be extended to include other areas in order that the service may be operated nearer the optimum.

2.2.3 Total Population

The total population based on the 1982 census and projected upto the year 2000 is represented on Table 2.1.

Table 2.1 : Total Population of the CDP Area

Year	Population
1983	280,000
1985	320,000
1990	450,000
1995	630,000
2000	884,000

1/ BCCI - Community Development Project, Orangi - "Socio-Economic Survey of Selected Clusters", Karachi, March 1984.

The population figures in Table 2.1 are for the entire project area and include a population of outlying area beyond present limits. Population estimates for zones within defined limits are presented in table 2.2.

Table 2.2 : Estimated Population in Zoned Areas

Zone	1985 Population Density (person/ha)	2000 Population Density (persons/ha)	1985 Total Population	2000 Total Population Within Defined Limits
High Density Z-1	375	700	22,500	42,000
Medium Density Z-2	275	500	182,000	325,000
Low Density Z-3	130	350	37,700	101,500
		TOTALS	242,200	468,500

The population zones were defined based on field verified population densities of selected clusters and information elicited from already executed sanitation surveys of given areas.

2.2.4 Population Densities

The zonal distribution of population densities used for design purposes are shown in Drawing Number - 1. These may be verified and revised as more information becomes available during the life of the project and as regularization, planning and development proceed.

3.0 GENERATION AND COMPOSITION OF ORANGI REFUSE

3.1 General

In the absence of adequate records for Orangi, or even Karachi in general, various refuse sample analyses were undertaken to assess its composition and relevent physical and chemical properties. Samples for the analyses were obtained from communal waste bins distributed over the project area and from the refuse unloaded from side loading collection vehicles used to service the communal bins. Direct analyses of the domestic refuse at source was also undertaken. Plastic bags were issued to 50 houses, selected at random, and the waste collected over a period of 4 to 6 days removed for analysis. This exercise besides providing information on the composition of the domestic refuse and its characteristic properties also provided a means by which an assessment was made of the rate of generation of refuse within the community.

Questionairres were applied throughout the project area covering over 120 dwellings, in order to ascertain disposal practices. The results of all investigatons related to the generation, composition and characteristics of the refuse are discussed in this section.

3.2 Composition of Orangi Refuse

Detailed analyses of the composition of refuse found in communal storage bins, refuse collection vehicles and domestic premises are presented in Table 3.1. Relevant physical and chemical analyses of the same samples are also presented therein. The composition of refuse varies according to land use patterns and seasons. The following represent an average composition, on net weight basis, for present refuse production.

Organic and Vegetable Matter	55% to 60%
Sand, Dust and Ash	10% to 15%
Stones and large	6% to 10%
Rags	5% to 8%
Paper and Cardboard	3% to 5%
Glass, Crockery and Earthen pots	1% to 2%
Plastic	1% to 2%
Rubber and Leather	0.5% to 1.5%
Bone	0.8% to 1.5%
Metals	0.2% to 0.5%

TABEL 3.1

ANALYSES OF ORANGI REFUSE - SEPTEMBER AND OCTOBER, 1984

TEST	Nature of Material	Communal Bin Baluch Colony	Communal Bin Sector 14-D	Communal Bin Tauheed Colony	Garbage Collection Vehicle	Garbage Collection Vehicle	Garbage Collection Vehicle	Domestic	Domestic
COMPOSITION ANALYSES (Wet Weight)	Organic and Vegetable Matter	49.8	53.2	60.2	59.3	54.0	54.4	63.0	61.5
	Sand, Dust and Ash	23.4	10.1	11.2	6.7	9.4	11.1	12.5	14.2
	Stones, and large debris	7.8	8.2	6.1	10.4	4.7	10.0	3.8	2.3
	Rags	5.0	7.5	6.8	5.8	13.5	6.8	3.4	5.6
	Paper and Cardboard	3.5	2.0	3.5	7.1	3.4	4.2	7.0	4.8
	Wood	1.4	1.3	1.9	1.7	1.3	1.4	1.0	1.1
	Glass, Crockery and Earthen Pots	1.8	1.2	1.6	1.5	6.8	2.1	0.5	0.9
	Plastic	1.0	1.1	1.0	2.2	1.3	1.8	1.5	1.7
	Rubber and leather	0.6	0.7	0.9	2.5	1.0	1.6	0.8	1.2
	Bone	1.5	0.8	1.2	1.0	0.9	0.8	1.4	1.2
	Metal	0.6	0.5	0.4	0.3	0.1	0.3	0.3	0.3
	Miscellaneous	3.6	13.4	5.2	1.5	3.6	5.5	4.8	5.2
PHYSICO-CHEMICAL ANALYSES	Density	345	286	311	250	259	229	265	380
	Calorific Value Kcal/tonne dry wt.	1580	-	-		1320	-	-	-
	Moisture Content	10.7	25.3	12.8	25.1	14.0	10.0	19.2	28.5
	Total Solids %	89.3	74.7	87.2	74.9	86.0	90.0	80.8	71.5
	Volatile Solids %	43.5	-	-	43.0	43.6	42.7	24.8	22.2
	Carbon C %	24.2	-	-	23.8	24.0	24.3	13.8	12.4
	Nitrogen N %	0.53	-	-	1.04	0.50	0.52	0.48	0.44
	Carbon/Nitrogen Ratio C/N	45.7	-	-	22.9	48.0	46.7	29.5	28.1
	pH	8.1	-	-	9.1	8.6	8.3	6.6	6.7
	Sample weight kg	147	109	122	134	109	121	102	114

Comparing the results obtained for Orangi during the course of this study to those obtained for other parts of Karachi in a separate study conducted by PCSIR 1/ (results of which are presented in Appendix 'B'), a very close correlation was obtained in the general composition of refuse in relation to all materials present in it except perhaps in relation to moisture content. The present study observed far lower values for moisture content. It is likely that the councils study was conducted during the wet season. The presence of, at times, considerable quantities of road sweepings in the Orangi refuse and the delayed collection frequency in the study area may further account for these variations. All refuse analyses, except the determination of in-situ bulk densities in communal bins were undertaken in accordance with the procedures established by the World Health Orangization 2/.

An overall total compostable matter of approximately 50 percent was observed. This value compares with 10 to 20 percent generally found in developed countries and is highest at the domestic source.

The low plastic, glass and crockery content observed indicate fewer problems in disposal especially where compositing is adopted. The very low paper and metal content recorded is indicative of the low socio-economic status of the community and possibly examplifies the extent of resource recovery practised in the community. Very small percentages of ash content was observed although the area is not supplied with piped gas. Average physico-checmical properties of the refuse are given below:

Moisture Content	10% to 15%
Density (Kg/m^3)	250 to 300
Calorific value (Kcal/Kg)	1500 to 1600
Total solids	85% to 90%
Volatile solids	42% to 44%
Carlon	24% to 24.5%
Nitrogen	0.5% to 0.7%
Carbon/Nitrogen ratio	40 to 48
pH	8.1 to 8.6

1/ Ref: Beg, M.A.A., Mahmood, S.N., and Naeem S., "Environmental Problems Part-I, - Solid Wastes, Their Evaluation", Pakistan Council for Scientific and Industrial Research (PCSIR), Karachi, 1984.

2/ Ref: Flitoff, F., "The Management of Solid Wastes in Developing Countries", WHO Regional Publications, South East Asia Series, No.1, 1976.

With regard to the physical properties, once again a close correlation was observed between the Council's reported values and those obtained in the present study. Large variations were however observed in the values quoted for carbon and consequently the carbon to nitrogen ratio. It is not readily evident which method of determining total carbon was utilzied in the council's study. If however, the carbon values are computed from the measured volatile solids 1/, then a close relastionship is observed between the results reported by the Council and those determined during the course of the present study.

The average bulk density of domestic refuse appears to undergo various transformations from source to final disposal. The direct measurement of domestic refuse density at source revealed that the density was indeed high; usually within the range 265 to 380 Kg/m^3. However these desnsities represent refuse collected over a period of 5 days which besides the effects of natural consolidation was also perhaps subject to manual compaction by the householders who cooperated in providing domestic refuse for analysis. Sample checks of freshly dumped refuse suggested that the naturally occuring domestic refuse density at source is of the order of 170 Kg/m^3. Direct analysis of refuse accumulated over a period of 24 to 48 hours, although not undertaken in the present study, would no doubt be useful in confirming this value.

The bulk densities of the refuse found in communal bins average 315 Kg/m^3. However, when loaded on to the side loading refuse collection vehicles they were observed to be noteably less; approximately of the order of 245 Kg/m^3. This is primarily due to the refuse handling procedures currently practised in the area and discussed in the detail in Section 4.2.3. The change in the average bulk density of the refuse from soruce to final disposal is depicted schematically in Figure 3.1.

1/ Percentage Carbon $\%c = \frac{(100 - \text{percentage ash})}{N}$. The value of N is said to lie between 1.72 and 1.8. Ref: Bhide and Sunderesan, "Solid Waste Management In Developing Countries", Indian National Scientific Documentation Centre, New Delhi, 1983; and Rabbani, Findal and Kulota, "Composting of Domestic Refuse", Environmental Sanitation Information Centre, Asian Institute of Technology, Bangkok, 1983.

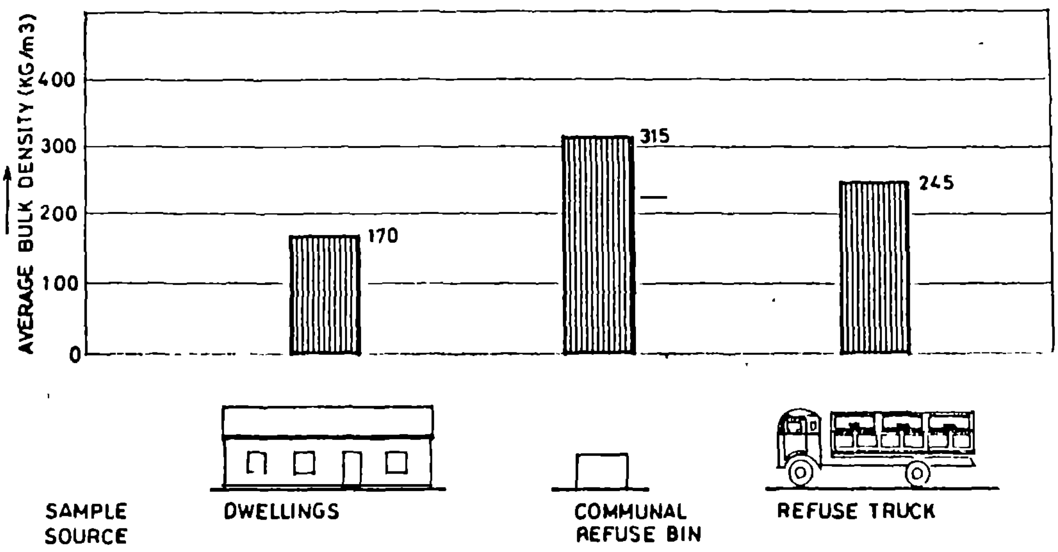


FIGURE 3.1 - VARIATIONS IN BULK DENSITY OF REFUSE AT DEFERRENT STAGES OF HANDLING.

Clearly the highest bulk density is obtained in communal refuse bins. Although bulk density is a basic planning parameter in solid waste management studies, the fact that the investigations undertaken by PCSIR failed to determine this parameter for the samples analysed, it is not possible to verify the values obtained in this study. The presence of a relatively large quantity of sand and dust observed in a sample obtained from a communal bin (sample analysis No. 1 in Table 3.1) placed on the side of one of the main arteries in Orangi, was observed to result in a large bulk density. Being a main road, it is more than probable that road sweepings would have been deposited in the bin and may account for the increased quantity of sand and dust found in it.

In general the nitrogen content of the Orangi refuse appears to be low (on average 0.52%). However, the presence of animal excreta on occasions results in increasing considerably the overall percentage nitrogen in the refuse. This is invariably accompanied by an increase in moisture content. Although the volatile solids of samples obtained directly from domestic sources were observed to be low, this however should not be interpretted to mean that it contains a low percentage of organic matter. This is but a direct consequence of the sampling technique adopted. The sometimes advanced state of degradation of the refuse collected over a period of 5 days is the principal reason for such low values since some of the organic material would no doubt, have escaped in a gaseous form. Similarly the low carbon to nitrogen (C/N) ratios of these samples are a consequence of the same sampling technique adopted in the analysis since degradation will promote the removal of carbon as carbon dioxide and consequently reduce the C/N ratio. The fact that some decomposition took place is indicated by the low pH values recorded for the domestic sample. The C/N ratio of Orangi refuse is generally high with values of the order of 47 being common. This implies that where treatment of refuse by composting is proposed supplementary nitrogen inputs in he form of animal manure, nightsoil or digested sludge would prove benefical in reducing the ratio to within the optimum range of 30 to 35. The pH was observed to be in the weak alkaline range and signify that the refuse contains little, if any, industrial wastes. An average calorific value of 1400 Kcal/kg was obtained by analysis; this while being approximately half that usually observed in industrialized countries, represent almost twice that quoted as average in Indian cities. Although the percentage paper content in the refuse was found to be low, yet, a larger value than expected, was obtained for its calorific value. The large percentages of rags in the refuse may account, in part, for these increased values.

3.3 Quantity of Refuse

The quantity of refuse produced from domestic sources in Orangi as estimated by the application of questionairres, field observations and direct measurements at the domestic source. The results of the refuse survey conducted by questionairre application is discussed in Section 4.1.1. The results of these investigations when compiled seem to indicate that the average daily production of domestic refuse amounts to approximately 1 litre/person/day.

Direct measurements of the rate of waste generation, by weight, obtained by distributing plastic bags to householders, revealed that this rate usually lies between the range 0.10 to 0.19 Kg/person/day.

On average the rate of waste generation was found to be 0.17 Kg/ person/day. Similar rates of refuse generation is quoted for Indian cities 1/. The average rates of generation of waste weights and volumes elicited from these investigation confirm the average domestic refuse density value of 170 Kg/m^3 indicated in the preceding section. The low weight and volume recorded in this study is once again indicative of the present socio-economic status of the community and the extent of resource recovery practised in the area.

Industries in Orangi are, at present, few indeed and most are confined to cottage industries producing footwear, textiles, plasticware and carpets. Since most of the scrap material is recycled, in one form or the other, very little is actually discarded in the refuse. Markets and commercial areas do however produce larger quantities of refuse. It is difficult at present to estimate the quantity of refuse generated on these premises. However, it is unlikely that commercial sources would yield a volume in excess of 12 percent of the total volume of domestic refuse generation in the area. Including industrial refuse, an estimated 15 percent increase in the overall volume would result. The suggested non-domestic refuse generation rates were obtianed as a result of interviews conducted with the establishedinformal sector which undertakes the removal of refuse from commercial areas and from other published data.

3.4 Future Trends

It is anticipated that there will be a steady and continuing change in the yield, composition and density of the refuse in the years ahead, and it is considered that:

Weight will increase by about 2.2% per annum; and
Volume will increase by about 12.7% per annum.

1/ Ref: Bhide and Sunderesan, "Solid Waste Management In Developing Countries", Indian National Scientific Documentation Centre, New Delhi, 1983.

TABLE 3.2

PREDICTED REFUSE GENERATION DATA

YEAR	POPULATION	NUMBER OF HOUSEHOLDS	REFUSE 1/ DENSITY Kg/m³	REFUSE YIELD 2/ PER PERSON KG		TOTAL REFUSE YIELD			
				DAILY	YEARLY	WORKING 3/ DAY TONNES	WORKING DAY VOLUME m³	ANNUAL TONNES	ANNUAL VOLUME m³
1985	320,000	42,100	345	0.20	73	78	226	23,400	67,800
1990	450,000	59,200	300	0.225	82	123	410	36,900	123,000
1995	630,000	82,900	250	0.25	91	191	764	57,300	229,200
2000	884,000	116,300	200	0.275	100	295	1475	88,500	442,500

1/ Density as obtained in communal storage facilities.

2/ Includes 15% increase to take account of industrial and commercial contributions.

3/ A 300 day working year is assumed.

These changes will arise due to increased socio-economic standards, a concomitant consequence of which would be the increased usage of packing materials, paper, cardboard, plastic, metal cans and bottles. Less attention would be paid to resource recovery. As development proceeds the control of refuse disposal and street debris and litter and the improvements in road paving and kerb construction will bring about a reduction in sand, stones and general street debris contained in the refuse collected.

The moisture content of solid waste will vary according to weather conditions and methods of storage and collection. Having regard to the methods likely to be adopted and those proposed in the present study a moisture content of about 20 percent is indicated.

The calorific value of the refuse would increase with time given the more frequent usage of paper and the reduced presence, in the refuse, of sand and debris. At present the calorific value of the refuse was measured to be of the order of 1400 Kcal/Kg. This is anticipated to rise to 1725 kcal/Kg over a period of 10 years and would continue to increase with the anticipated changes in composition.

Biologically the refuse produced, would, with appropriate sanitation intervention contain less biological contaminations. Although limited biological analyses undertaken indicate that the extent of contamination is indeed small, this no doubt is a result of the fact that only an estimated 5 percent of the refuse is actually collected at present. Clearly the introduction of a more comprehensive collection system will no doubt detect a greater extent of contamination resulting from the 2 to 4 percent of the houses which possess no form of sanitation, however rudimentary and from the faeces of young children who do not use any sanitary facilities. Only a sustained programme of sanitation intervention and concomitant user awareness programmes could help arrest the situation.

4.0 EXISTING FACILITIES AND SERVICES

4.1 General

In order to ascertain the refuse storage and collection facilities and the extent and efficacy of the waste disposal service currently available in Orangi, extensive interviews were conducted with officials of the KMC responsible for the service. Interviews with personnel concerned with the management of refuse in Orangi, including a thriving informal sector, were also executed. Questionairres were applied to elicit information regarding the various modes of domestic refuse storage and disposal adopted by the community and to assess the extent of service provided. The results of these investigations and other field observations are discussed in this section. Current refuse disposal methods practised are also included.

4.2 Present Refuse Collection System

4.2.1 Results of Sample Domestic Refuse Survey

A sample domestic survey covering 120 dwelling, evenly distributed over the six councillor areas and selected on a random basis, was conducted to obtain parameters essential or the planning of solid waste management and indications of the general storage and disposal practices within the domestic premises. The survey also sought to elicit information on current refuse yields and extent of resource recovery. The main findings of the survey are summarized on Table 4.1.

The survey revealed that, at present, only 5 percent of the refuse currently generated in Orangi was removed by the authorities. This compares with a service level of 33 percent for Karachi in general 1/. The low level of service provided in the area has instigated a process of "Self-help" in resolving the problem of refuse disposal in the community. While some of the solutions adopted are ingenious, most are unsatisfactory and imply indiscriminate disposal practices.

1/ Ref: Jackson, D.W., "Solid Waste Management Components", Karachi Special Development Programme, Ministry of Planning and Development, September, 1984.

TABLE 4.1 - SAMPLE DOMESTIC REFUSE SURVEY RESULTS

QUESTION	PERCENTAGE (10 20 30 40 50 60 70 80 90 100)
Number of residents per house	
Upto 4	12.00
5 to 6	23.00
7 to 8	32.00
9 to 10	16.00
Above 10	17.00
Where is refuse stored on the premises	
In a pile on the floor	29.00
In a G.I. bucket	5.00
In a 18 litre oil tin	63.00
In a plastic or paper beg	1.00
Others	2.00
Rate of refuse field per person per day	
Less than 0.5 litres.	18.00
0.51 to 0.75 litres	28.00
0.76 to 1.0 litres.	13.00
1.1 to 1.25 litres.	8.00
1.26 to 1.50 litres.	16.00
More than 1.50 litres.	17.00
How often is the refuse removed for disposal	
Once a day.	45.00
Once in two days.	15.00
Once in three days.	11.00
Once in four days.	17.00
Once a week.	10.00
Other.	2.00
Who removes the refuse for disposal.	
Household members.	100
Sweepers.	
Other.	
Where do you dump your refuse.	
On open plots.	14.00
In the nullah.	11.00
In front of the house.	30.00
On the road.	16.00
In K.M.C. dust bins.	2.00
Other.	27.00
What happens to the dumped refused.	
Stays there.	30.00
Removed by K.M.C.	4.00
Burnt.	63.00
Other.	3.00
What materials do you retain for sale.	
Do not retain any material for sale.	46.00
Paper, Plastic, Sandals and Cloth.	12.00
Roti (unlearened bread).	43.00
Glass.	32.00
Metals.	13.00

The survey found that the average number of residents per household varied from one Councillor area to the other. The average number was observed to vary from 5 persons per house to 9 persons per house with an overall aggregated average value of 7.6

A majority of the residents stored their refuse in used oil tins. The canisters have a capacity of 18 litres. Approximately two thirds of the population adopted this form of domestic storage while a majority of the rest used no containers at all. The refuse in these houses was invariably swept to a corner of the house. Only a single house was observed to store the refuse generated in a plastic bag.

Over forty percent of the houses produced 5 litres or less of refuse daily and just over thirteen percent produced a full conister of refuse daily. On average however each house produced 40 percent the volume of a canister daily amounting to an approximate volume generation rate of 1 litre per person per day.

Over fifty percent of the households dump their refuse once a day. It was interesting to note that over twenty percent stored their refuse for four days prior to dumping and. as many as twelve percent only dumped their refuse once a week.

Refuse was dumped predominantly in front of the houses. Over a third of the houses selected this location for refuse dumping. This was invariably on the road in front of the house. Hence over half the community dumped their refuse in the streets, while a sixth dumped on open plots. The dumping of refuse on open plots are invariably approved of by the owner who sees an opportunity to raise the general ground level of the plot and promote the levelling of uneven ground. Approximately forteen percent dumped their refuse in the nullah 1/, which given the number of possible riparian dwellings

1/ Non-perennial storm water course.

in the project area represent a considerable porportion selecting water courses for disposing of their refuse. Often the refuse is disposed of on the sides of the bank which during periods of rain is conveyed downstream. Only 2 percent of the population dumped their refuse in KMC communal bins, (1.1 diameter, 0.85m deep galvanized iron containers without a base). Clearly the limited number of persons utilizing the KMC bins is indicative of the extremely limited number of communal storage bins provided in the area. Only an estimated 8 bins with an overall storage capacity of 6.5 m^3 is currently available in the area.

Approximately two thirds of the refuse disposed of in the project area is burnt by the residents at their selected dump sites. Besides the five percent currently collected by KMC, just under a third of the refuse disposed of receives no form of treatment except those which take place by natrual means.

Just under half the population practised some form of resource recovery, of which the sale of roti (unleavened bread) and used bottles and glassware were the more popular items for resale. Metals, paper and plastics were other items recovered for reuse.

Except for a few premises, storage at individual dwelling and other properties is unsatisfactory - uncovered and non-standard receptacles are in general use - much waste is disposed of directly into the streets and to vacant land. Open dumps of waste can be observed in many places and these dumps and the subsoil beneath is heavily infested with fly larvae. Organic wastes, which comprise of half the refuse, human and animal excreta and various forms of containers will attract pests of many kinds, including dogs, and are an ideal media for fly and mosquito breeding.

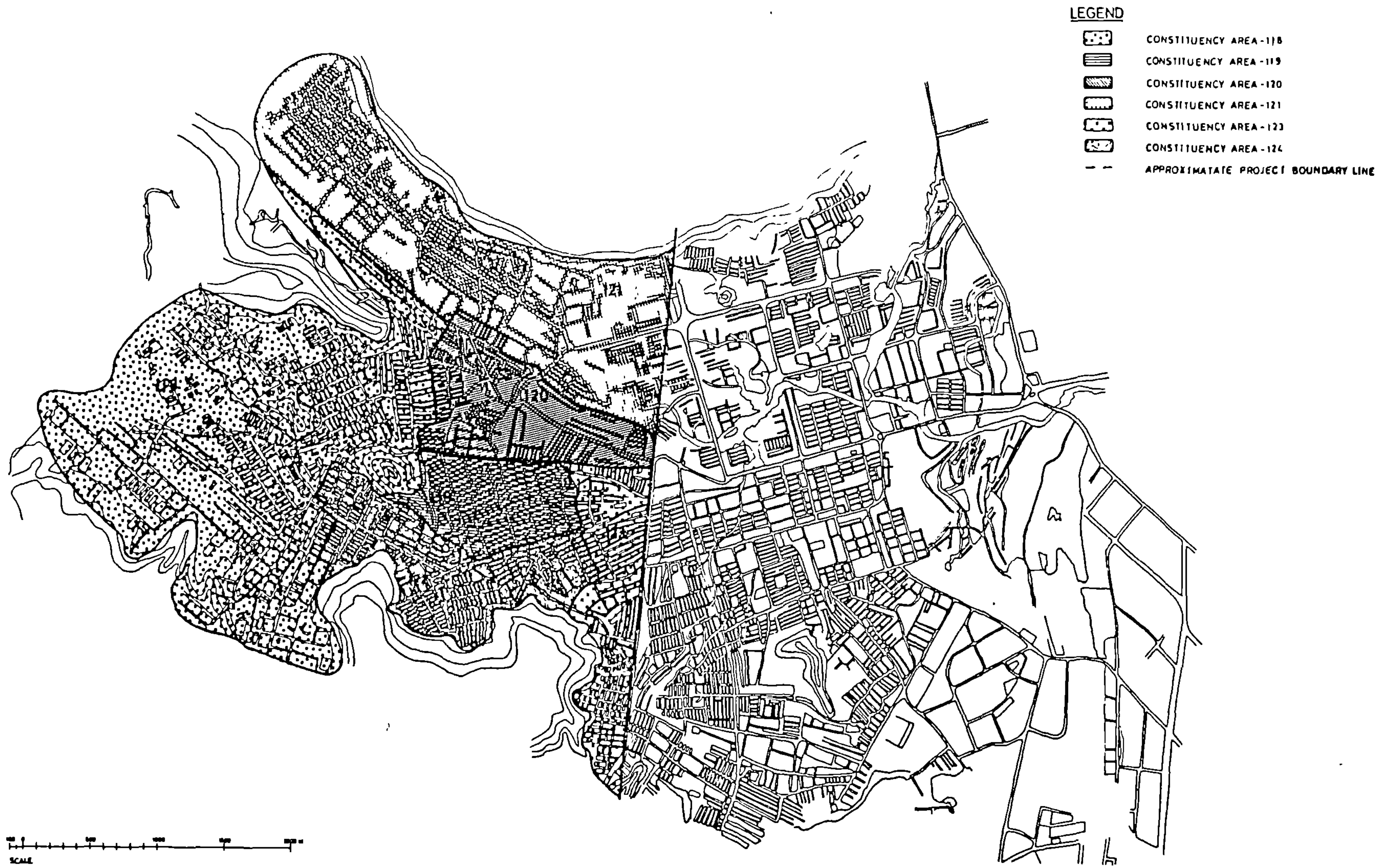
4.2.2 Institutional Structure and Method of Operation

At present the collection and disposal of refuse is under the direct control of the Health Department of the Karachi Metropolitan Corporation (KMC). The organization of refuse disposal service in Orangi is by councillor areas. The delimitation of the Councillor areas within the project boundary is shown on Drawing No. 2. Of the fifteen Councillor areas in Orangi the project area comes under the administration of of six Councillors. There are three Sanitary Inspectors for all fifteen councillor areas with each having juridication over five areas. Each of the Sanitary Inspectors is assisted by a Sub-Sanitary Inspector.

Eight street sweepers are assigned to each constituency area. Women are also employed for this task. Four $6m^3$ side loading collection trucks with tipping device is said to service the whole of Orangi. A single refuse vehicle serves five constituency areas each of which is served once a week. The vehicle is assigned to collect and dispose of all the refuse in a constituency area within a day and is operated on a rotary basis where after one week all five Councillor areas will be served by the vehicle. Since most of minor staff employed in the collection and disposal of solid waste are Christian, both Friday and Sunday are declared holidays and the service is only provided for the remaining five days of the week. A section gully emptier is also provided for every five Councillor areas and operates on a similar rotary schedule with a frequency of return to any Councillor area of once every five weeks. However, unlike the refuse collection vehicles the suction emptier is retained in each Councillor area for an entire week prior to moving on to the next area. The emptiers are used to desludge the innumerous vaults and leachpits ubiquitous in the area.

4.2.3 Refuse Collection Service

The present refuse collection and disposal service is not adequate for the needs of the area. Much waste is dumped in the streets, on vacant ground and in the nullahs. The habits of the community will only be changed by providing an adequate service and community motivation. A system of street sweeping is carried out by sweepers with hand brooms and sisal baskets. The considerable number of unsurfaced streets and footways and the widespread practice of dumping building materials in the streets results in dirty dusty (and in wet weather muddy) conditions which are a hazard to public health and which creates a considerable impediment to effective cleaning.



BCCI CDP	SOLID WASTE MANAGMENT IN ORANGI		
	MAP OF ORANGI SHOWING CONSTITUENCY AREA		
	SCALE AS SHOWN	DATE NOV. 1984	DRG NO 02

Collected sweepings including refuse tipped in the streets is conveyed to pick up points. This is usually a place where the dumping of refuse by the community has led to its continued usage. Often it is only paved streets which are swept at irregular frequencies and usually confined to making tidy the margins of the paved area. Alternatively the collected sweepings may be dumped in any of the 8 G.I. communal refuse bins. Each bin has an approximate capacity of $0.8m^3$. It is indeed remarkable that a population of 300,000 persons are only provided with an effective overall communal storage facility of approximately 6. 4 m^3. This however is a measure of the inadequacy of the present day service.

The steps involved in loading the refuse from communal bins to side loading collection vehicles is indeed labour intensive, laborious and time-consuming. When excreta are present in the refuse, and collection infrequent, the task is positively unpleasant besides being a threat to the health of those who undertake this operation with minimum of protective equipment and clothing. The steps involved in the operation is dipicted on Plate No.1 in Appendix-I.

When the collection vehicle arrives 3 to 5 men load it by fork, basket and shovel. Initially the G.I communal bin is rolled to a side leaving the refuse in place. Loading of the vehicle then proceeds. The vehicle is unsuitable for loading light refuse because its load height is too high, it was originally designed for heavy materials. Further, it does not carry a reasonable load of refuse, total pay loads of just under 2 tonnes were observed to be the norm The truck however is designed to carry pay loads of 5 tonnes. When loaded above the side boards, litter after blows about. The time taken to load the vehicle was recorded during the course of the present study and was observed to average 11 minutes to load the refuse from a single $1.0m^3$ communal bin. This implies that an overall loading time of nearly an hour is spent per trip. Since the vehicles are expected to travel a distance of 10Kms to North Karachi for dumping, more time is taken to load and unload the vehicle than to transport the refuse and return to collect more. This is clearly uneconomical. The great deal of time spent in loading the vehicle also accelerates its wear.

4.2.4 Summery of Existing Facilities in Study Area

Following equipment and labour is currently provided in the project area.

Labour:	Middle Management	-	1	Sanitary Inspector
			1	Sub-Sanitary Inspector
	Vehicle Staff	-	1	Driver
			4	Collectors
	Unskilled labour	-	48	Sweepers

Communal Storage Facilities:	6 to 8 $0.8m^3$ G.I. Communal bulk containers.
Transport:	$6m^3$ side loading collection vehicle.
Expected daily number of trips per vehicle:	3.

4.3 Present Refuse Disposal System

Refuse disposal practices in Karachi have suffered chronically from two absolutely fundermental problems; lack of secure disposal sites and lack of any standards of control. These are at present only two official refuse dump sites. The first situated in North Karach is the larger. The second site situated in Korangi has come to exist since haulage distances from neighbouring areas to North Karachi is indeed considerable. The location of these official sites are shown in Figure 4.1. The unfortunate result of the deficiencies in disposal sites and controls in disposal methods has been that random use has been made of numerous sites, both close to development and towards the margins of the settlement, where refuse has been tipped in an uncontrolled manner, untreated and unconcealed upon the ground surface with no levelling and no cover. Even in the official refuse dump sites such as the North Karachi site, fly infested, heaps of burning refuse with rising clouds of smoke present a serious hazard to public health.

Temperature inversions, common at night during certain seasons of the year, give rise to the formation of hazy smog, fast becoming a permanent feature of Karachi's horizon.

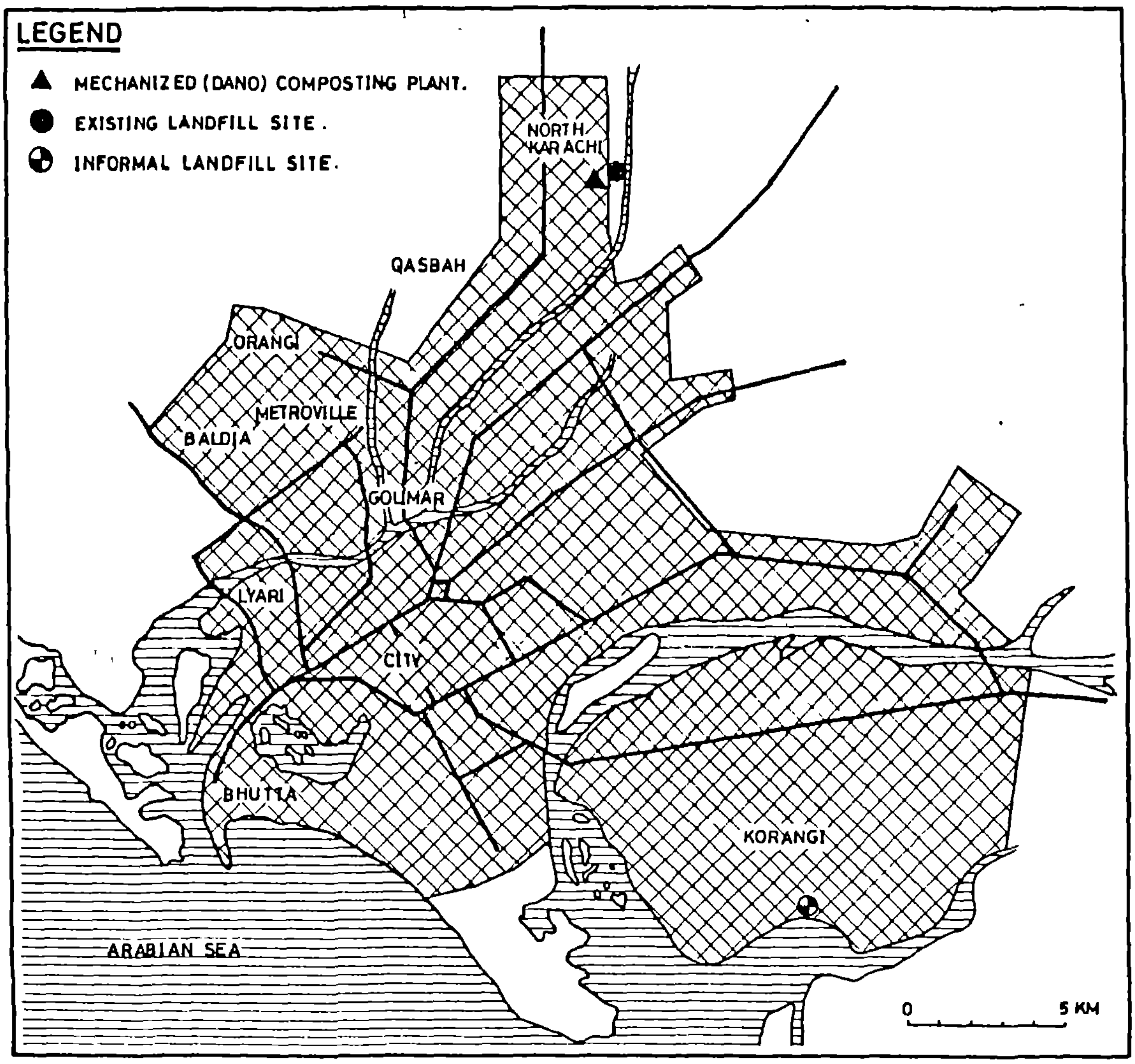


FIGURE 4.1 - REFUSE DISPOSAL SITES IN KARACHI

The large haulage distances from Orangi to the North Karachi site-- the nearest to the project area - has initiated the common practice of disposing of collected refuse at unoffical sites within Orangi and its periphery. Drawing No.3, attempt to represent some of the larger sites presently utilized in Orangi and contains information regarding the distribution and capaicty of communal storage facilities found in the project area.

The creation of unofficial, uncontrolled refuse dumps results in increased usage of the same site for further dumping by private individuals. This problem is particularly exacerbated in Orangi, where the use of bucket latrines by just under half the community has led to the dumping of nightsoil in adjoining sites. Sludge collected by tankers from vaults and septic tanks in the remaininghouses is also discharged within the built-up area with little discretion.

Since depressions and low-lying areas become the prime targets for indiscriminate dumping of refuse, sludge and nightsoil nullahs are often chosen for this purpose. However, this practice presents a sever threat to public health especially during rainy seasons when they possess the potential to contaminate the entire downstream area. The picking of fly maggots (larvae) by crows and other birds was Also observed at these sites and further underline the potential risk of diffused contamination the practice presents, in the study area. Large numbers of rodents were also observed to infest these sites at night. Typical sites used for waste disposal in the project area are shown in Plates 2 and 3 in Appendix-I

At least the practice has resulted in the unsightly despoliation of the seenery and at worst it has precipitated a real risk to public health and, in some cases, obstruction of water courses. the present lack of an adequate disposal site to the North - West of Karachi has meant that, although Orangi is situated at the periphery of the city, in order to reach the North Karachi site, it is necessary to travel east an average haulage distance of 10 kms, after passing through developed areas. The creation of a refuse dump site at the north - western periphery of Karachi would improve greatly the service provided to the western sector of Karachi and discontinue the usage of unofficial sites such as the one contiguous with river Lyari near

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its outfall to the sea and other sites near Baldia and SITE. The lack of authorized and planned tipping sites results in considerable vehicle and personnel time being spent in travelling to unofficial tip sites randomly distributed. No logical collection vehicle routing is therefore possible, and a substantial proportion of refuse generated within the study area remains uncollected.

At present refuse carried to both official and unofficial tip sites is dumped on the ground. No plant is available for moving or levelling refuse or for covering it with granualr material. A general code of practice for landfill tipping of waste is appended to the report. In addition to the direct importance of proper refuse disposal practices, it is essential to the efficient running of the refuse service that adequate and secure tipping sites are obtained, so that logical collection routes can be planned and implemented.

4.4 The Informal Sector In Orangi

Two types of informal sectors are active in the management of solid waste within the community. The first comprises of private individuals who, by means of animal-drawn carts, transport refuse from markets and commercial properties to dump sites selected at their discretion. Charges for the service vary with haulage distance, and since these are often specified by the propriator of the concerned establishment, tend to be as close as possible to the point of collection. For example a charge of Rupees (Rs.4) is levied per trip to transport the collected refuse from Pakistan Bazar - a large market area in constituency area 119 - to an adjoining open field.

However, the prosperous of all informal sectors concerned with solid waste management in Orangi are the "Cabadiwalas" - used material marchants. There are an estimated 5 used material depots within Orangi (see Plate No.4 in Appendix-I) which purchase a variety of material for recycle. The depots are served by an estimated 50 door-to-door sales persons who purchase the used articles directly from he householders. A cart mounted on four bicycle wheels is often used by these individuals for this purpose (See plate No. 5 in Appendix-I). The recovery of used material is also undertaken by an army of individuals who pick-up and transport in sacks any discarded matrial of value they may come across. The market value of a variety of used materials recovered from refuse is presented in Table 4.2. Large numbers of families are at present involved in recycling material recovered from the North Karachi and Korangi tips. Where the entire family including children, participate in this activity daily family profits of Rs.300 are not uncommon.

TABLE 4.2 - UNIT PRICES OF RECYCLED MATERIAL

MATERIAL	UNIT PRICE (Rs./Tonne)
Plastic	5000
Tin	6000
Brass	40000
Copper	18000
Aluminium	16000
Galvanized Iron	1000
Bottles	500
Broken Glass	250
Paper	2000
Footware	5000
Roti (Unleavened bread)	1000
Car Battery	2500

5.0 INVESTIGATIONS INTO COMPOSTABILITY OF ORANGI REFUSE

5.1 General

Over two-thirds the composition, by weight, of Orangi refuse is compostable. Where compost may be produced at nominal expenditures they offer various possibilities in planning solid waste management. These include:

- possibility of resolving the problem of refuse disposal by placing the entire operation in the hands of a private individual, who ensured a market for the product could operate the service for profit motives.
- possibility of training persons handling the disposal of night-soil to adopt a treatment process which could produce an environmentally safe and stable product.
- create an income generating activity to extend the current resource recovery practice to make maximum use of the majority element in the overall composition of the refuse.
- produce a soil conditioner at a nominal expense which could be utilized to establish green areas within the community.
- possibility of reducing the overall expenses of providing this essential urban service.
- possibility of reducing haulage distances.
- possibility of processing sludge obtained from individual and communal septic tanks and valuts in the project area.

In order that this method of treating and processing refuse could be adopted in the physical and social context of Orangi, it was necessary that detailed investigations be carried out to establish appropriate methods of composting and monitor the nutritive value of the final product. The investigations undertaken to identify simple methods of producing compost, the required process controls and the establishment of the value of the end product as a soil conditioner is discussed in the present section.

Only aerobic composting processes were considered due primairly to the multiple advantage[1] they offer over anaerobic processes. Aerobic composting is characterized by a rapid decomposition rate and release of a great deal of energy in the form of heat from the oxidation of organic carbon to carbon dioxide. Advantages of aerobic composting include:

- Odour-free operation and end product. Malodour decreases consumer demand
- High temperatures attained during decomposition makes compost safe from pahogenic contamination.
- Rapid decomposition and stabilization results.
- Physical space requirements are limited.

Some nitrogen loss due to high temperatures and eventual alkaline conditions and the demand for greater handling are the main disadvantages of the process.

5.2 Factors Affecting Aerobic Composting

Aerobic conditions are necessary for the development and establishment of Thermophilic bacteria which bring about the rapid degradation of organic matter. In order that the process may be operated at optimum levels the provision of the following conditions is essential.

TABLE 5.1 - DESIRED VALUES OF COMPOST PROCESS PARAMETERS

PARAMETER	VALUE
C/N ratio of feed	30 - 35 : 1
C/P ratio of feed	75 - 150 : 1
Particle size	40 - 75 mm
Moisture content	40 - 60 %
Air flow	0.50 - 1.80m^3 air/day/kg volatile solids
Temperature	55 - 65°c
pH	7.5 - 8.5

The approximate nitrogen content and C/N ratios of various compostable materials are given elsewhere 1/.

Three techniques of producing compost with differing degrees of mechanization for application to differing scales of production were investigated. These included :

- Chinese Covered Pile system
- Window system
- Force aerated Pile system

5.3 Chinese Covered Pile System

In this method bamboo poles were placed 1m apart in a criss-cross pattern on a bedding layer of 0.15m of dry grass and vertical poles attached at the crossing points. Refuse from Orangi was then mixed with 15 percent poultry wastes and water added to the mixture prior to placing it on the resulting structure.

Large stones and cloth were removed from the refuse prior to mixing. No shredding or grinding was done prior preparing the feed. Clay soil containing some straw was worked to a consistency which facilitated the placing of the earth on the pile and lightly tamped to seal the pile against heat and moisture loss. The straw was added to the soil in order to reduce shrinkage cracks during drying. After a day, when the soil covering had dried, the poles were removed to leave air ducts. The steps involved are illustrated in Figure 5.1 and Plates 6,7 and 8 in appendix I . Thermocouples placed inside the covered pile were used to monitor the process, since temperature, perhaps, more than any other parameter is a good process performance indicator. The material was noted to have stabilized after 14 days. The results obtained utilizing this method of composting are given below.

1/ Ref: Rabbani et. al., " Composting of Domestic Refuse", Envirnonmental Sanitation Information Centre, Asian Institute of Technology, Bangkok, October, 1983.

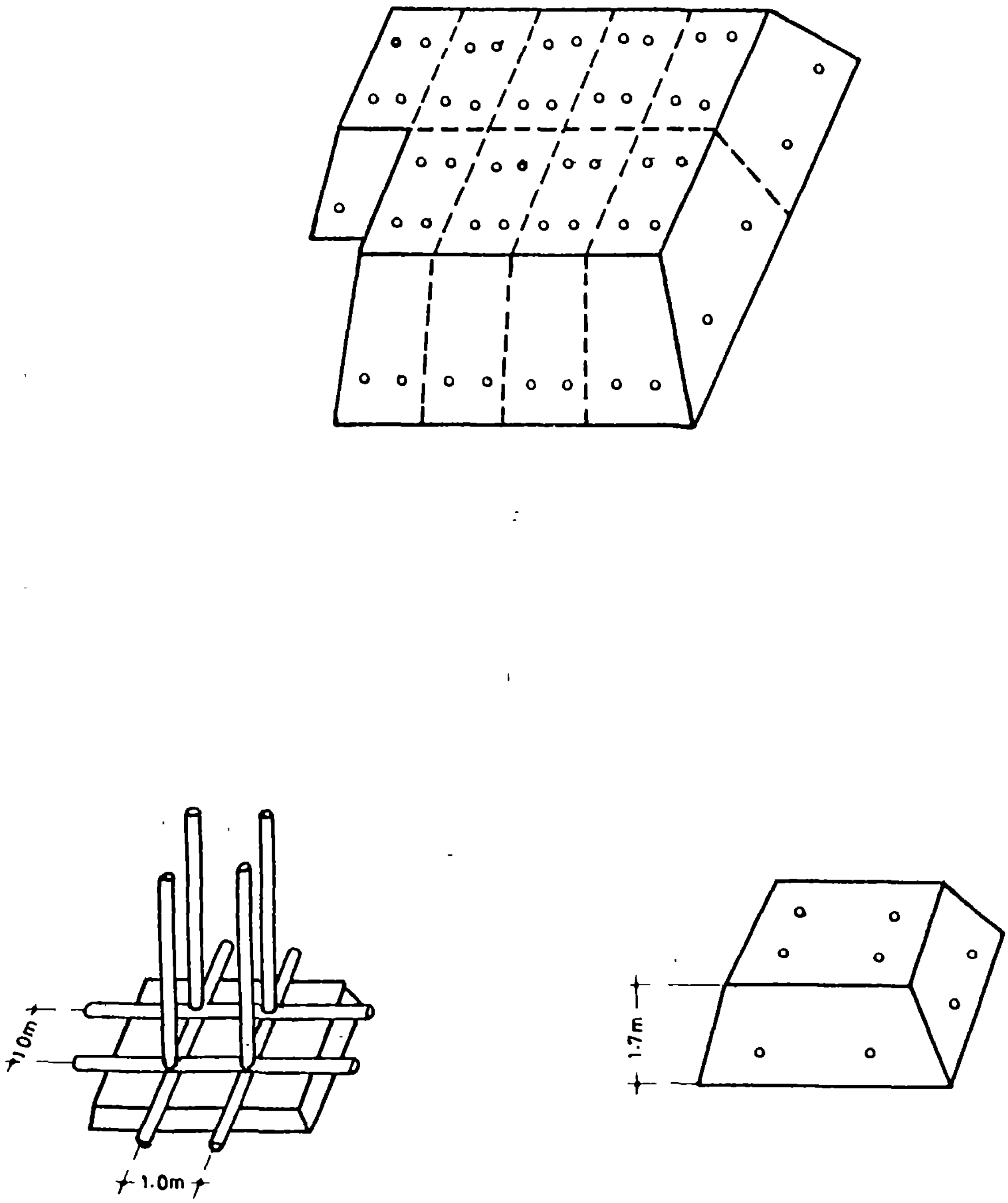


FIGURE 5.1 - LAYOUT OF CHINESE AEROBIC COMPOSTING SYSTEM

5.3.1 Results of Chinese Composting

The composition of the refuse utilized in the experiment is presented in column 6 of Table 3.1. The temperature changes observed during the composting process is presented in Figure 5.2. Temperatures as high as 66°c were attained in a few days and thus maintained for upto 10 days. The maintaining of these high temperature for considerable durations would ensure the distruction of all pathogens. For example ascaris eggs-one of the toughest excereted pathogens - would be destroyed within a few minutes and thus render the final humus safe. This feature of the Chinese composting system, like all other aerobic composting sytems, presents great advantages in processing refuse and nightsoil and producing a safe humus rich in nitrogen.

The physico-chemical analyses of the raw refuse used, the feed prepared and the resulting compost is presented in Table 5.2.

TABLE 5.2 - PHYSCIO-CHEMICAL ANALYSIS OF REFUSE, FEED AND HUMUS - CHINESE SYSTEM

PARAMETER	SAMPLE			
	Raw Refuse	Feed	Humus after 14 days	Humus after 30 days
pH	8.3	7.8	7.4	7.3
Moisture Content %	10.0	33.0	45.0	16.9
Total Solids %	90.0	67.0	55.0	83.1
Volatile Solids %	42.7	48.8	21.0	30.0
Carbon C %	24.3	27.0	12.2	12.6
Nitrogen N %	0.52	0.77	0.99	1.0
C/N Ratio	46.7	35.0	12.3	12.6
Potossium	-	-	-	1.1

Since stabilized compost, prior to maturing - technically referred to as green compost - has a C/N ratio between 9 and 13, it may be observed that degradation of the organic matter in the feed was complete by the fourteenth day. High nitrogen potassium contents 1.0 and 1.1 percent respectively were found in the final compost.

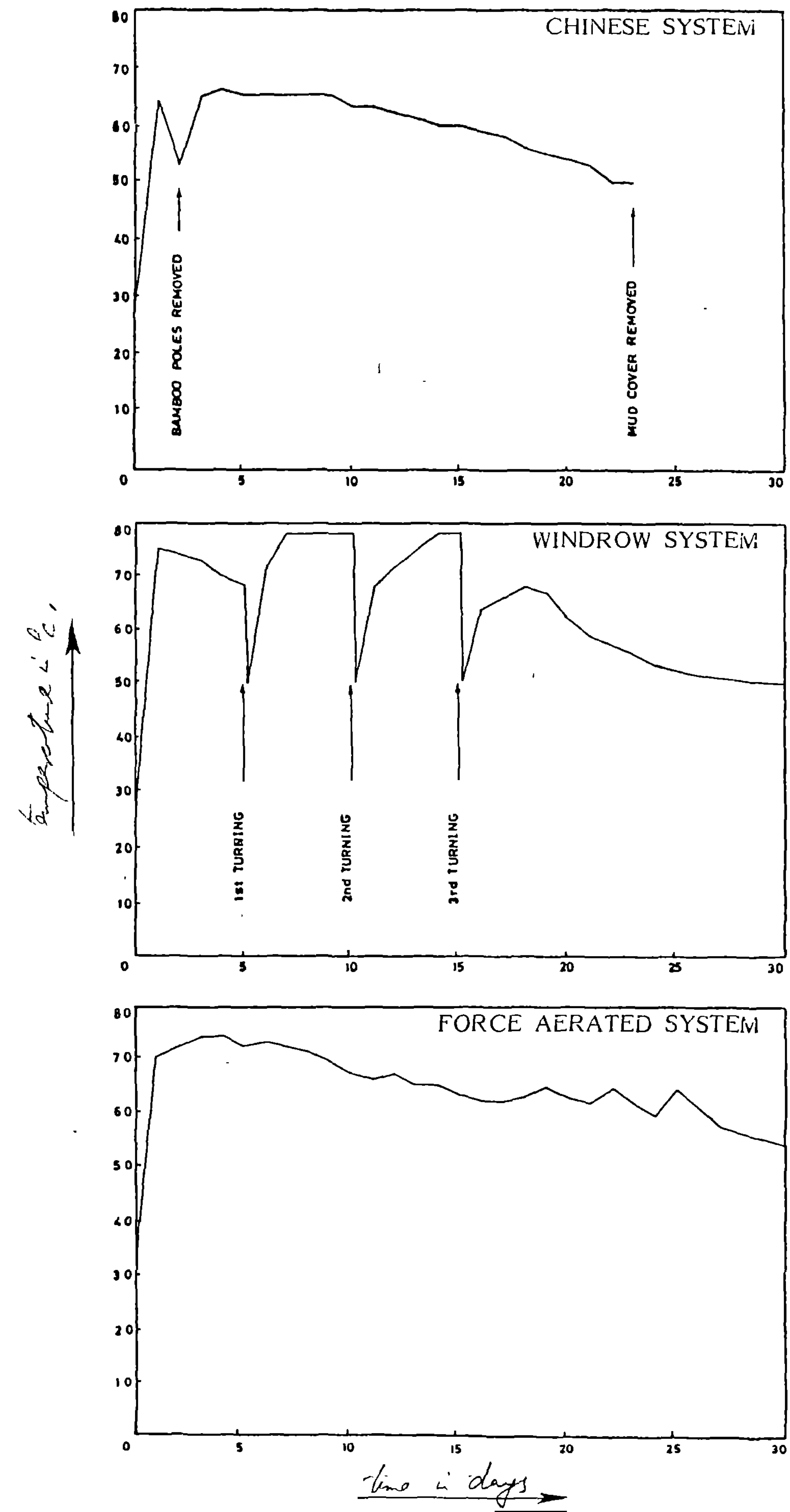


FIGURE 5.2 - THERMOGENESIS OF TESTED SOLID WASTE COMPOSTING SYSTEMS

Although it was not possible to determine the phosphorus content of the final compost it is expected that this value would also be approximately 1.0 percent. A 20 percent weight loss between feed and final compost was measured. The percentages, by dry weight, of material in the final compost are as follows;

Compost	-	70.9%
Bulkly Orangi Material for recycle	-	4.3%
Stones, galss and crockery	-	8.8%
Wood	-	1.8%
Bones	-	0.8%
Cloth, leather, plastics and matels	-	13.4%

An overall compostable fraction of approximately 71 percent was observed. This indicates that over two-thirds the composition of refuse generated in Orangi may be composted yielding a good humus with high nutrient contents. The bacterialogical quality of the initial feed and final compost is presented in Table 5.3 as may be observed from this table no enteric bacteria were detected in the final compost. Further work is still in progress to ascertain survival levels of helminthic ova in the final product. It is however expected that no viable ova would be observed. The final compost material obtained in presented in Plate 9 of Appendix-C.

TABLE 5.3-RESULTS OF BACTERIAL ANALYSES-CHINESE SYSTEM

ORGANISM	NUMBERS PER GRAMME OF REFUSE	NUMBER PER GRAMME OF COMPOST
Total Bacterial Count	$8.3x10^7$	$6.3x10^6$
Fungi	$5.0x10^6$	$3.3x10^5$
Actinomycetes	$1.6x10^6$	$1.6x10^6$
Enteric Bacteria	$5.3x10^3$	0.

5.4 Windrow System

Windrow is an aerobic composting process applied extensively in India and requires very little mechanical equipment. it has been adopted for processing refuse from cities with large popualtions. As may be inferred from their name "windrow" or "Open" composting systems are characterized by the placing, in the open, in elongated piles, the refuse appropriately adjusted for moisture and C/N ratio. In the experiments conducted with this method of composting refuse from Orangi was mixed with 10 percent poultry wastes and water added to the mixture prior to placing it in a windrow. As in the chinese system, large debris and cloth were removed from the refuse prior to mixing . Once again no shredding or grinding was done previous to mixing.

The windrow was turned on the 5th, 10th and 15th day following mixing. Once again thermocouples were placed inside the covered pile and the temperature recorded daily. The composition of the refuse obtained may be assumed to be identical to that used in the chinese composting system since their source was essentially one. The general layout of the test windrow pile is presented in plate No.10 of Appendix - I.

5.4.1 Results of Windrow Composting

The temperature changes observed during the composting process are presented in Figure 5.2. Very high temperatures were attained, with values of 78^{o}c not being uncommon. This temperature while being desireable in relation to the destruction of pathogens, resulted in large nitrogen losses as may be observed from Table 5.4. Since even the more resistant pathogens are destroyed after a few minutes at temperatures in excess of 60°c in composting systems temperatures above 65°c are counter productive. Further, when high temperatures are reached those micro-organism, causing the breakdown of the organic material themselves, begin to die and hence retard to process.

The physico - chemical analysis of the raw refuse used, the feed prepared and the resulting compost is presented in Table 5.4.

TABLE 5.4 - PHYSICO - CHEMICAL ANALYSIS OF REFUSE, FEED AND HUMUS - WINDROW SYSTEM

PARAMETER	SAMPLE					
	RAW REFUSE	FEED	FIVE DAY HUMUS	TEN DAY HUMUS	FIFTEEN DAY HUMUS	HUMUS AFTER 30 DAYS
pH	8.3	8.5	7.1	7.5	7.7.	7.8
Moisture Content %	10.0	33.0	36.0	33.0	32.0	39.0
Total solids %	90.0	67.0	64.0	67.0	68.0	61.0
Volatile solids %	42.7	43.0	36.0	33.0	29.4	10.0
Carbon C %	24.3	23.8	20.0	18.4	16.3	5.6
Nitrogen N %	0.52	0.67	0.58	0.56	0.52	1.47
C/N Ratio	46.7	35.6	34.0	32.8	31.0	11.9
Potassium						0.72

From the results presented in Table 5,4 it is evident that the window process took more time for the organic matter to stablize. Nitrogen loss was initially recorded and is perhaps a consequence of the high temperatures attained during degradation. Potassium levels were also observed to be lower than expected. Clearly it may prove useful if turning was performed more frequently, than adopted during the course of this experiment, as a means of controlling temperature to within the optimum range of 60-65°c. Unlike the Chinese system of composting, the window system possesses very little ability to control process parameters within defined optimum ranges. In both experiments (Chinese Pile and Windrow) the initial moisture content was observed to be somewhat below the desired optimum. A 20.4 percent weight loss was observed during composting and is a result of the liberation of principally carbon dioxide but also other gases. The percentage by dry weight of material in the final compost are as follows:

Compost	-	68.7 %
Bulky Organic Material for recycle.	-	2.5 %
Stones, glass and crockery	-	18.2 %
Wood	-	2.0 %
Bones	-	0.5 %
Cloth, leather, plastics and metals	-	6.0 %

An overall compostable fraction of approximately 69 percent was obtained. This indicates once again that it is possible to compost over two-thirds of the refuse generated in Orangi. The bacterial counts found in the feed and final compost is presented in Table 5.5. As in the case of the Chinese system, a safe material free from enteric bacteria was obtained.

TABLE 5.5 - RESULTS OF BACTERIAL ANALYSIS - WINDROW SYSTEM

ORGANISM	NUMBER PER GRAMME OF REFUSE	NUMBER PER GRAMME OF COMPOST
Total Bacterial Count	9.3×10^6	4.5×10^5
Fungi	9.0×10^5	8.0×10^6
Actinomycetes	4.5×10^5	4.3×10^3
Enteric Bacteria	6.8×10^3	0

5.5 Force Aerated Pile System

This method of composting is similar to that of the windrow system except in that the need for turning the refuse is obviated by placing a pipe grid below the feed and above a 0.15 layer of dry grass. A 6.6mxl.5m, 75mm diameter G.I pipe grid was utilized in the control experiment. The height of the pile was made upto 1.2m, although heights of the order of 2.5m are more common. The pipe grid contained a series of orifices varying from 2mm to 6mm from the end nearer the pump to the far end respectively. Three rows of alternating series of holes were made in the pipework in a manner similar to that of subsurface drains. The pipe work was connected to a 3 horsepower air blower. The blower was automatically activated for 15 minutes every 45 minutes by means of a timer. The feed was prepared using Orangi refuse and 10 percent poultry wastes and water added as required. A layer of dry grass was placed over the feed to provide insulation and protect against water loss. The general layout of the system before and after placing the mixed refuse feed is shown in Plates 11 and 12 in Appendix I.

5.5.1 Results of Force Aerated Pile Composting

The composition of refused used in preparing the mix is presented in columns 4 and 5 of Table 3.1. The temperature changes observed during the composting process are presented in Figure 5.2.

Temperatures were observed to drop to around 50 to 55°c when the pump was operated but on average temperatures were observed to be of the order of 65°c. The control of temperatures to within the optimum range was observed to be maintained in the force aerated pile during composting.

The average physico - chemical analysis of the raw refuse used, the feed prepared and the resulting compost is presented in Table 5.6.

TABLE 5.6 - PHYSICO - CHEMICAL ANALYSIS OF REFUSE, FEED AND HUMUS-FORCE AERATED SYSTEM

PARAMTER	RAW REFUSE	FEED	21 DAY HUMUS
pH	8.9	8.1	8.35
Moisture content %	20.0	39.5	33.5
Total solids %	80.0	60.5	66.5
Volatile solids %	43.3	34.0	33.5
Carbon C %	23.9	18.8	18.6
Nitrogen N %	0.57	0.84	1.4
C/N	42.0	22.3	13.3
Potossium			1.0

From the above results it is evident that the organic degradation process proceeded well and that stable organic material is produced. High nitrogen, and potassium contents of 1.4 and 1.0 percent respectively were observed in the final compost. Phosphorous content although not determined is expected to be approximately 1.0 percent.

A 21.5 percent weight loss during composting was measured. The percentages by dry weight of material in the final compost are as follows:

Compost	70.9 %
Bulky Organic Material for recycle	3.5 %
Stones, glass and crokery	11.0 %
Wood	2.1 %
Bones	0.4 %
Cloth, leather, plastics and metals	12.1 %

An overall compostable fraction of approximately 71 percent was obtained. This once again confirms the high compostability of Orangi refuse with the ability to produce a valuable humus rich in nutrients. The bacterial contents of the initial and final compost is presented in Table 5.7. Once again, due to the high temperatures attained during the composting process the final humus is free from enteric bacteria. However temperatures, usually around 45°c, were observed on the surface of the pile and for this reason it is probable that some pathogenic organisms may be found on the surface of the pile. Work aimed at confirming this observation is current in progress and would be made available to the project in the near future.

TABLE 5.7 - RESULTS OF BACTERIAL ANALYSIS - FORCE AERATED SYSTEM

INDICATOR ORGANISM	NUMBERS PER GRAMME OF REFUSE	NUMBERS PER GRAMME OF COMPOST
Total Bacterial Count	$8.3x10^6$	$5.5x10^6$
Fungi	$8.6x10^5$	$7.4x10^5$
Actinomycetes	$4.6x10^5$	$4.2x10^5$
Enteric Bacteria	$6.8x10^3$	0

5.6 Compost Application Rates

Experiments are currently underway at PCSIR to ascertain application rates for Orangi compost to act as a fertilizer. The results of these experiments will however only be available at the commence of the following year. Guidelines to determine the required application rates for various crops and pastures are given below:

The percentage available Nitrogen(N) = percentage inorganic nitrogen +0.2x percentage organic nitrogen

The required N application in Kg/ha $x \frac{1}{\text{Kg available N}}$ Required compost in tonnes/ha

where required N application = N required by crop - available soil N.

Typical compost application rates for different plants and crops are given in Table 5.8. These values are for exclusive use of compost. Best results are however obtained when compost is applied together with chemical fertilizers.

TABLE 5.8 - RECOMMENDED COMPOST APPLICATION RATES FOR DIFFERENT PLANTS AND CROPS

PLANT OR CROP	COMPOST RATE IN TONNES/HA/YR	METHOD OF APPLICATION
Sod, Turf, New Lawns	100 - 200	Till into surface layer prior to seeding.
Sod, Turf, Established lawn	50 - 75	Apply onto surface as required.
Other cercals, cotton, and agronomic crops	As required, e.g., Corn 50	Till into soil prior to planting.
Free Nurseries	50 - 100	Till into soil prior to planting.
Pastures	50 - 100 depending on species	Till into soil prior to planting.
Pastures	50	Apply onto surface periodically.

Source: Shuval, H.I. et. al., "Appropriate Technology for Water Supply and Sanitation - Nightsoil Composting", World Bank, Washington, December, 1981.

5.7 Conclusions

Orangi refuse is eminently suited for composting. Successful trials were conducted in composting the refuse using three simple techniques all of which, may with ease, he adopted for application in Orangi. The final compost was observed to have high levels of nitrogen,and potassium. Their controlled application in Orangi has the potential to produce on environmentally stable product with the positive benefit of producing green areas within it. Such an application could change the present day dreary landscape and help stabilize slopes in the area.

It would appear that good control over the windrow process would be necesary in order to limit temperatures attained during this form of composting to the optium range. However, the windrow is the simplest of all three techniques and for this reason most appropriate for adoption in Orangi. The institution concerned with adopting this method of *processing* refuse in Orangi could however select the most appropriate method having initially investigated the financial implications of each method. In turning composting material in the windrow system it is recommended that the external material of the pile prior to turning, be placed at its centre and that material which was at the centre of the pile be place on its periphery. This would ensure that pathogens present in the feed would at sometime during the composting period be in an environment of elevated temperatures which would in turn result in their demise.

It was observed that drying of surface material, even when covered with suitable insulating material, in the forced aerated pile resulted in a decrease in its temperature. The wetting of surface material, on occassions, could prove beneficial in accelerating degradation and ensuring the destruction of pathogens. Since the C/N ratio in Orangi refuse is above that considered optium for quick degradation, it is advantageous to add some animal waste material. In the experiments conducted poultry waste was utilized since many poultry farms are found within the project area and its periphary. Sludge obtained from vaults and septic tanks may also be utilized for this purpose. The addition of approximately 10 percent of either sludge or animal waste would be more than adequate in ensuring that sufficient levels of nitrogen are maintained for optimum bacterial activity.

The low percentages of glass and plastics detected in Orangi refuse make it ideal for composting. These materials vitiate the product for agriculture. Large quantities of cloth are usually found in Orangi refuse. Very little degradation of cloth was observed during composting due primarily to the large cellulose and lignin contents in them. All experiments were conducted without having undertaken initial shredding or grinding. However, where commercialized plants are to be set-up then, the inclusion of these processes prior to mixing the feed would no doubt accelerate the composting process and produce a homogeneous end product.

Over two-thirds of Orangi refuse is compostable and represent precirely that portion of the refuse which is not utilized in anyway today.

6.0 PROPOSED FUTURE REFUSE COLLECTION SERVICE

6.1 General

The purpose of the refuse collection service is to provide an effective and efficient system for the removal of all solid household, instituational and tradewastes from the project area, either from the individual premises or central collection points. Removal of street litter and waste is also an essential part of the service. The method of collection and its application to the various areas in Orangi is discussed in detail in this section.

In commissioning a comprehensive refuse collection and disposal system, the frequent cleansing of all streets and open spaces and the removal of all existing refuse dumps within the area would incentivate community participation in maintaining clean the project area. The ensurence of a reliable refuse collection system would instill community confidence and sustain positive community cooperation. The creation of public awareness through the many contacts that the present project has with the community, and especially as part of the user-awarness programme proposed for the lane and household sanitation component of the project, could further encourage and reinforce community cooperation. The project could also promote community cooperation through the display of prominently located posters and leaflets. Clearly any such display should be graphically depicted and not composed exclusively of a text.

6.2 Primary Refuse Storage

6.2.1 Individual Premises

The current practice of improvised primary refuse storage leaves a lot to be desired. Refuse is stored in non standard containers and leaps on the floor. The use of old 18 litre oil tins has evolved as the most popular primary refuse storage container. However, since these containers are susceptible to damage due to rough handling, and corrode rapidly, their adoption in Orangi has had limited success. The corrosion of the domestic refuse containers are particularly accelerated by the liberation of weak organic acids during the initial phase of anaerobic degradation which in tern is facilitated by the high temperatures. The container being made of metal cannot be readily washed out. The residue often gives rise to odour and further encourages rapid deterioration. No cover is presently provided to the containers which promotes fly breeding.

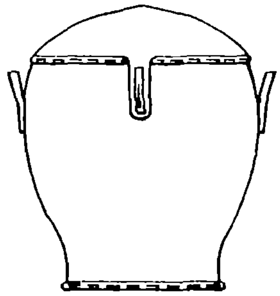
An alternate domestic container fabricated from used tyres was developed during the course of the present study and is presented in Plates 15 and 16 of Appendix-I. The capacity of the container may be varied with individual requirements but for general use consistent with proposals presented herein, the adoption of a 30 litre container is recommended. The proposed container being made of rubber, and possessing a lid, overcomes the two major inadequacies of the present day containers. The domestic refuse container proposed is illustrated in Figure 6.1. The cost of the container is expected to be of the order of Rs.25.

6.2.2 Markets and Commercial Areas

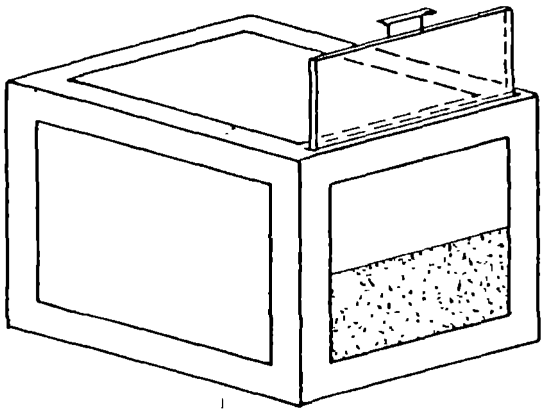
Containers similar to those proposed for use in domestic premises may be adopted for use in small markets and commercial areas. They may however be of a larger capacity of 50 litres. The use of containers which may be placed directly on the back of a 3-wheel moped (see section 6.5.3 for details) having an overall effective capacity of $0.5m^3$ is proposed for premises generating larger quantities of refuse. Where very large quantities of refuse are generated $5.0m^3$ roll-on, roll-off containers are envisaged. An appropriate charge may be levied for the provision of the 0.5 and $5.0m^3$ containers.

6.2.3 Institutions

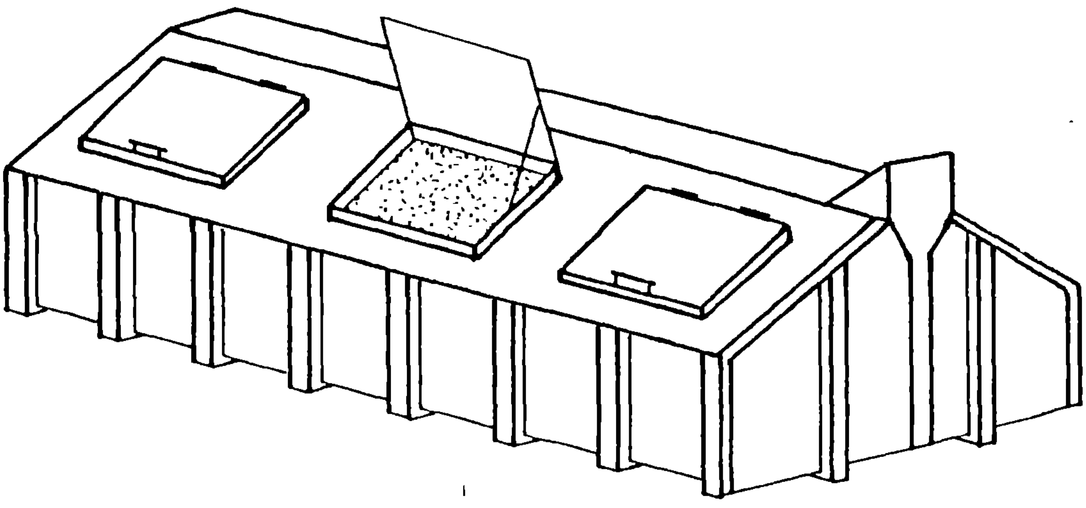
Covered primary refuse storage containers should be provided for large instituations, such as schools, and their capacity determined in relation to their rate of waste generation. The provision of $0.5m^3$ load-on load-off, containers of the type referred to in the preceding section may be distributed



30 LITRE DOMESTIC STORAGE BIN



0.5m³ INSTITUTIONAL & COMMERCIAL STORAGE CONTAINERS MOUNTABLE ON THREE-WHEELED MOPEDS



5 - 10m³ ROLL-OFF CONTIANERS

FIGURE 6.1 - PROPOSED REFUSE STORAGE CONTAINERS

and collected at an adequate frequency. Large institutions and special premises may be covered by bulk containers of the roll-on roll-off type with a capacity of $5.0m^3$.

6.3 Secondary Refuse Storage Containers

All refuse collected from domestic sources, and small commercial establishments, by means of moped would be transported to communal secondary storage facilities comprising of $10.0m^3$ roll-on, roll-off containers. Twenty five such containers would be required to serve the entire project area. Attempts to utilize $1.0m^3$ capacity containers in parts of Karachi has had little success since they are often turned over by scavangers. The design of the $10.0m^3$ container proposed is such as to disuade scavanging or where this is done, the spreading of refuse around the container is not facilitated. Illustration of the container are presented in Figure 6.2, together with other containers proposed.

6.4 Container Requirements

A summary of container requirements during the initial implementation of the service is presented in Table 6.1.

TABLE 6.1 - PRIMARY AND SECONDARY REFUSE STORAGE CONTAINERS FOR INITIAL SERVICE

CONTAINER CAPACITY	DOMESTIC	COMMERCIAL	INSTITUTIONAL
30 litre rubber bins	42,100	-	-
50 litre rubber bins	200	500	200
500 litre demountable contianer	-	35	15
5000 litre roll-off container	25	3	2

6.5 Collection of Refuse

6.5.1 General

The suitability of refuse collection methods is influenced by many factors individual to a particular application. The main parameters are, however, method of storage, quantity of waste, avoidance of nuisance such as smell and fly breeding and the discouragement of illicit dumping.

6.5.2 Frequency of Collection

In the high density areas although many households can store waste on their own property, commercial premises such as shops and markets have very limited space. Further, the refuse they produce is more susceptible to degradation and hence smell With a frequent collection service the amount of waste to be collected at any one time is reduced but, it is necessary to keep waste collection to a minimum. In the present circumstances a daily collection from commercial clusters is recommended and where these are sparsely distributed it is recommended that they be considered as any other domestic premises.

Elsewhere in the study area, having regard to the recommended primary and secondary storage methods and the climate in Karachi, a twice weekly collection is proposed. In institutions since the refuse is unlikely to contain large quantities of putresible organic material, frequencies of collection may be infrequent. However, the frequency of collection is best determined for each institution according to the quantity of refuse generated dīaly and the storage capacity provided. The collection Frequency should, however, under no circumstances exceed once a week.

6.5.3 Collection Method

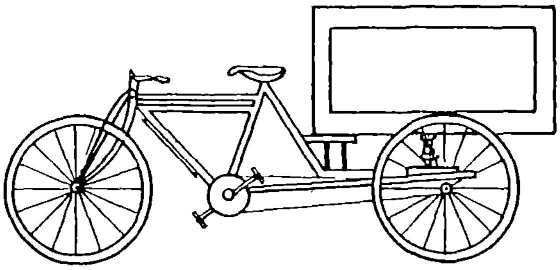
It is proposed that the project area be judiciously divided into areas each served by one collector who would have the responsibility for waste collection on a twice weekly basis in his section. Each collector would be equipped with a three-wheeled moped containing a single container of 500 litre capacity. Such a container carrier can be handled conveniently by one man and would not impede traffic. He would only remove the refuse contained in those bins placed on the kerbside by the householders and shopkeepers.

It is envisaged that each collector would service an area containing six hundred houses. Since collection is expected to be effected once every three days the collector would be expected to service two hundred premises each day. Three such collectors shall operate in adjoining areas and transport the entire quantity of refuse collected to a single $10m^3$ roll-on, roll-off container parked at a site located central to all three areas. A secondary area is thus established containing three collector serviced areas. Twenty-five such areas would be required within the project area each containing a centrally located $10m^3$ roll-on, roll-off container. These containers thus become the secondary storage containers and act as mini transfer stations.

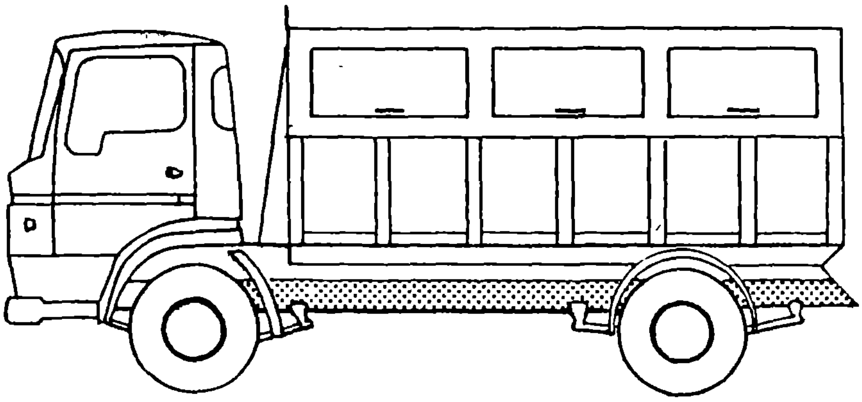
Five roll-off tippers, making five trips per day would remove all secondary storage containers to tip. The location of the containers within a defined secondary collection area shall be established in liaison with the community and the leaders within the area. Sites presently used for dumping refuse and other open areas will no doubt emerge as favourable locations. Access and manoeuverability will establish their appropriateness. The sites would be carefully selected and operated to be functionally efficient and aesthetically acceptable.

6.5.4 Collection Vehicles

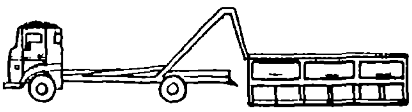
The initial investigations undertaken in developing and planning a refuse collection and disposal service revealed that the highest bulk density of Orangi refuse was found in the communal containers. This observation, discussed in section 3.2, prompted the selection of refuse vehicles which would obviate the need for double handling by loading the refuse collected in the communal bins in to a collection vehicle since this results a reduction in the bulk density and hence transports less refuse. Clearly the highest pay-loads would be obtaiend when the communal container is itself transported directly to the disposal site. This is conveniently achieved by means of demountable contianers which may be rolled-on and rolled-off the chassis of the collection vehicle with the aid of hydraulically operated arms. The proposed secondary collection vehicle is illustrated in Figure 6.2. Since tipping too is done hydraulically the refuse is quickly deposited and the vehicle may then return to the collection area for more refuse.



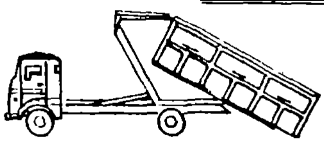
PRIMARY REFUSE COLLECTION VEHICLE



SECONDARY REFUSE COLLECTION VEHICLE



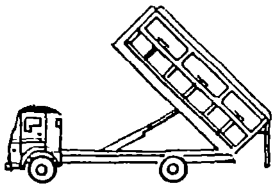
Ready to lift container



Container being pulled on to truck

Container placed on truck

Truck ready for Transport



Trunk dumping collected refuse

MODES OF OPERATION OF SECONDARY REFUSE COLLECTION VEHICLE

FIGURE 6.2 - PROPOSED REFUSE COLLECTION VEHICLES

The greatest disadvantage of the refuse collection vehicle currently in use is the great deal of time spent loading the carrier. Often these carriers have to be manually unloaded too. The adoption of roll-off tippers eliminates the need for delays in loading and unloading, which besides accelerating the process also results in considerable savings in engin wear and demands less manpower. Since no time need be spent loading the proposed collection vehicle substantial time saving results and a larger number of roll-off containers may be served with a single vehicle. For this reason only five roll-off tipper vehicles are required initially for the whole of the project area. Although compression vehicles have recently been introduced to Karachi their possible application in Orangi, at present, is indeed limited given inadequate access and large numbers of unsurfaced roads. They were developed for use in industrialized countries where densities are often less than 150 Kg/m^3. After compression, densities of the order of 500 Kg/m^3 are obtained. However, the naturally available higher densities of Orangi refuse eliminates the need for such vehicles.

While roll-off tippers were selected for secondary transport vehicles, three wheeled bicycles were chosen for primary transport purposes. These vehicles are common in Karachi and is generally used to transport vegetables and fruit. It is proposed to fit a motor to them in order to facilitate their transit. The containers placed at the back of the three wheeled moped is so designed that, when full, it may backed-up against the one of the openings of the $10m^3$ container and by lifting the reverse side panel of the container, unload its contents directly into the roll-off communal container. Loading of the container placed at the back of the three-wheeled bicycle will be from the top of the container.

In selecting the primary collection vehicle various types of vehicles currently used in Orangi and other parts of Karachi were considered in the light of their possible adoption in Orangi. These included three-wheeled pick-ups with dustbins, donkey carts, wheelbarrows etc. However the three-wheeled bicycle offers the greatest promise under the present circumstances.

The general collection service as outlined would be served by only two types of vehicles; the three-wheeled moped and the roll-off tipper. They are proposed for primary and secondary collection respectively. Both vehicles are not expensive to purchase and have simple rugged and easily maintained mechanisms. They are simple to operate and are good general purpose vehicles well suited to the needs of Orangi.

As the area, expands and the population increases so the service will need to expand to maintain the same comprehensive service. It is also necessary to plan for an increasing volume of refuse; as the general affluence of the people increase so the use of packing and other similar materials will become more common and a consequent reduction in the density of the refuse will result.A consequential increase in refuse volume will follow. It is likely that compression vehicles would then prove to be more appropriate for Orangi especially as development in the area procedes and most roads become surfaced. This however, is unlikely to be the case over the next 15 to 20 years with which the present study is concerned.

The expansion of the city in area and in population will also require growth in the number of service vehicles and personnel. Table 3.2 gave projections of refuse volumes for future years and this information has been extended in Table 6.2 which contians estimates of collection vehicle requirements for the service is future years. This table only sets out the numbers of vehicles required in service, additional vehicles will be required to allow for maintenance and servicing but the specific number of extra vehicles may best be determined as the service develops and the average down time for repair is estimated. Initially at least five extra primary collection vehicles and one extra secondary collection vehicle are recommended.

TABLE 6.2 - REFUSE COLLECTION SERVICE - VEHICLE REQUIREMENT

	1985	1990	1995	2000
Total daily refuse production (m^3)	226	410	764	1475
Number of roll-off vehicle loads ($10m^3$)	25	41	75	148
Number of roll-off vehicles required 1/	5	8	15	30
Number of moped loads 2/	452	820	1528	2950
Number of mopeds required	75	137	255	492

1/ Based on five journeys per day allowing picking-up, travelling to disposal site, unloading returning and setting down.

2/ Based on six journeys per day allowing for loading, travelling to roll-off container, unloading and returning to collection area.

6.5.5 Collection of Special Wastes

For institutions and special premises such as hospitals, special containers which may be used on the same primary and secondary collection vehicles are recommended. These may either be $0.5m^3$ demountable contianers which may be transported on the three-wheeled mopeds or $5m^3$ bulk containers which may be transported using the same roll-off vehicle adopted for use in transporting the secondary collection communal containers. This wil allow two sizes of bulk containers to be available for use, $0.5m^3$ and $5m^3$. Either size may be used at these premises and may be collected and emptied as necessary. Similar bulk containers may also be hired out for use by building contractors or others to avoid the dumping of building rubble and waste in the public roads.

6.5.6 Cleansing of Refuse Containers

The periodic cleansing of all the containers and receptacles in public use is necessary on a regular basis. The cleansing of individual household bins must be the responsibility of the householder. Most of the containers may be transported to the central depot for cleansing, and washing. Lime may then be spread inside the container prior to reuse.

6.6 Street Cleansing

Effective street cleansing in the project area is presently difficult to carry out because of the large number of unsurfaced roads and footpaths. The situation should however improve gradually as development proceeds. The dumping of building materials and rubble in the streets, although not presenting a grave problem at the present time, would require close controls in future as more vehicles begin to ply the Orangi streets. The extension of the refuse collection service in providing, roll-off containers to remove these materials is recommended although its practical implementation, at this stage, not emphasized. A realistic service change may incurred for this purpose.

The proposed new collection system will result in a reduction in waste deposited in the streets and a consequent reduction in the requirement for street cleansing. It is recommended That the project, through its active participation in the development of Orangi and constant and extensive contact with its inhabitants undertake user awareness programmes aimed at instilling community participation in maintain Orangi clean.

Some street cleaning would however still be required. It is proposed that all street sweeping be carried out manually. The use of present day equipment is adequate. However, the use of brooms with a handle made of long and flexible fibres requiring long strokes by the worker standing erect as opposed to the current practice of exerting great force while bending over with a bunch of filaments should be given consideration. Clearly the workers preference should be adopted. Thirty able bodied sweepers, each equiped with a sisal basket, effective broom and shovel, should be adequate to maintain satisfactory cleanliness. Sweepings will be deposited at the nearest secondary storage roll-off container. The deposition of large quantities of grit should be discouraged. The sweepers would also be entrusted the responsibility of ensuring that refuse dumped outside the roll-off containers are placed within.

6.7. Pest Control.

Efficient solid waste management will make a dramatic reduction in the breading of flies, insects and rodents. This aspect of service will be enhanced by good and quick waste removal. The cleaning up of the present day open nightsoil dump sites within and outside the built up area of Orangi would have the greatest impact in pest abetement. Effective means by which this may be achieved are discussed in section 7. Present day waste accumulations in informal dumping grounds should also be cleared at the on set of the implementation of the proposed service.

6.8 Transport for Refuse Collection Service

The proposal outlined in the preceding sections of this document require, for their full implementation, a vehicle fleet which in the initial stage should comprise:-

- 30 - 10m^3 Roll-off containers.
- 5 - 5m^3 Roll-off container tippers.
- 75 - 0.5m^3 Moped containers.
- 75 - Three - Wheeled/ mopeds

Thorough maintenance and cleaning of vehicles should be carried out on a regualr basis. Provision for regular cleaning and minor servicing and lubrication should be made at a central transport depot. Full maintenance and repair facilities should be provided by the authority responsible for the operation of the service. The construction of a full vehicle repair and maintenance shop would be possible if the service was extented to other areas of Orangi and Karachi. A careful assessment of vehicle and plant requirements in the future should be made with acquisition of vehicles phased over the initial years to allow the service to expand with the development of the area. A policy of planned and phased replacement of vehicles should be implemented so that no vehicle life is allowed to exceed the economic optimum, commonly five to eight years.

Vehicle drivers should be competent and efficient and should be made responsible for the daily checking of their vehciles and the immediate reporting of any defects which may develop.

7.0 PROPOSED FUTURE REFUSE DISPOSAL SERVICE

7.1 General

The efficient and effective disposal of refuse is essential to the running of the refuse service as a whole. The present system of indiscriminate dumping has led to public opposition to the use of any land for the disposal of refuse. It is therefore essential that adequate planning and management of the refuse processing and disposal sites be undertaken to promote public acceptance.

It is proposed initially that a suitable area be acquired for processing the refuse into compost. It is recommended that this be undertaken in conjunction with sludge drying with sludge obtained from communal septic tanks presently being constructed in the area as part of the area sanitation intervention. The adoption of an integrated sludge drying and composting plant is proposed with the aim to resolve two major public health problems in the project area. The integrated plant would need to be adequate for the processing of the refuse collected from the entire project area although its extension to other areas may also be considered. The processing of the refuse by the proposed method besides arresting two public health problems in the area would have some productive value to the executing authority.

7.2 Selection of Appropriate Disposal Method

The state of the art of disposing of refuse include many processes and techniques. Sanitary landfill, composting, waste derived fuel production, pulverization, incineration are the more common of these processes. However, given the context of the present study area, only the former two techniques are considered applicable. While sanitary landfill is perhaps the cheapest means of disposing of the refuse, it is however, contrary to the general trend in a country where resource recovery is practised extensively. As stated before, the present day "Know how" of those involved in this informal sector prevents their adoption of techniques to recover, by processing, the largest proportional composition of the refuse. The diffusion of simple techniques by which compost may be prepared from the organic fraction of domestic and commercial refuse, amongst the informal sector, may well change the present day perspective. Where landfill has been adopted in Karachi, this has been executed in the most unhygienic and unsatisfactory manner. Guideliens for improving present day practices is presented in Appendix-D.

Since the present study seeks to provide a compreshensive and unified method of waste disposal the adoption of an integrated sludge drying and composting plant is recommended. The safe disposal of all sludge generated in Orangi together with the domestic and commercial refuse would have a very positive impact on both the environment and health of its residents. As a second option, sanitary landfil is suggested and details regarding both these forms of refuse disposal discussed in this section.

7.3 Sanitary Landfill

Sanitary landfill involves the deposit, spreading and compaction of waste and refuse in layers up to 2.5m deep and the continous application to exposed surfaces of a cover, 200 mm thick, of sand, soil or other suitable and inert material, with no waste left exposed at the end of each working day.

It is a scientific and satisfactory method which relies on the decomposition of waste by the action of micro-organisms, and its reduction to innocuous material with the passage of time. Bacterial action is rapid in the period immediately after the waste is deposited, when the temperature may rise to as much as 65°c, after which the rate of decomposition and temperature subsides. The initial elevated temperatures kill many of the disease organisms and fly and insect infestation.

The effective application of sanitary landfill methods requires the preparation of a plan of operation which must be strictly observed in each respect. The work, by its nature, is an "earthmoving" exercise and require proper equipment to achieve success. The guidelines presented in Appendix-D makes reference to the use of crawler bulldozers. This type of machine has however only limited capabilities, such as levelling and skimming and is not sufficiently versatile for the varied operations involved in this system of disposal.

The most efficient purpose made plant for tip operations is a mechanical loading shovel, mounted on wheels and fitted with special tyres or steel compator wheels and designed for the specific purpose of handling refuse. Such a machine will:

a) Excavate and load material for cover.
b) Excavate 'Bays' for the reception of waste.
c) Level and consolidate waste in layers, more speedily and effectively than a crawler bulldozer.
d) Apply, distribute and level cover material (especially in places with limited access).
e) Crush and break up bulky articles.
f) Lift and transport heavy items, and deposit them in places with difficult road vehicle access.

Strict supervision is required for all operations and especially in the control of vehicles on the tip. Routes to be followed and the method and point of tipping must conform with the plan of operation.

As stated in Section 4.3, it would appear that there is very little justification in transporting the refuse collected from Orangi, which in itself is on the periplhary of the present day developed area of Karachi, through built up areas such as Nazimabad to convey the refuse to the North Karachi tip. There is an imperative need for an alternate tip site located west of Karachi to which all wastes generated in the western section of Karachi may be transported. The acquisition of suitable refuse tip sites for this purpose is a task which would have to be pursued by the Karachi Metropolitan Corporation. Due consideration must be given to the geology of the tip and the possibility of pollution of underground water in selecting appropriate sites.

7.4 Composting

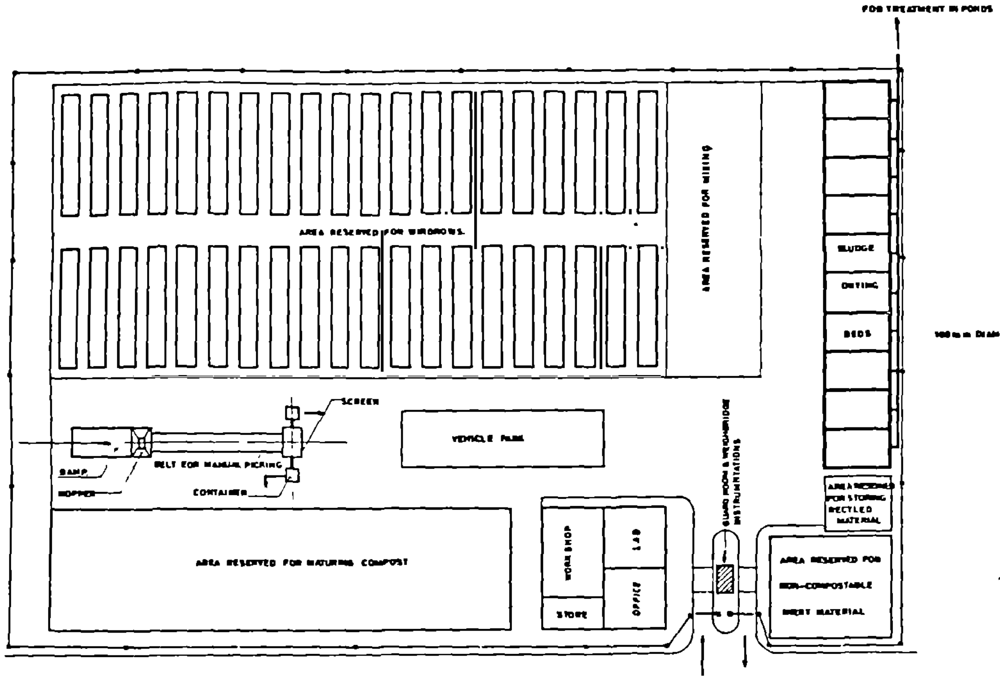
Composting is a simple natural method of stabilizing organic refuse and involves the stacking of waste on a paved area, in a form that ensures aerobic conditions within the heap. Three simple methods of procesing refuse to produce compost were identified and pilot scale production set up to assess the merits of each system and undertake analyses of the nutriative value of the end product. Details of each method of composting is presented in Section 5.0.

While windrow has the advantage of being the simplest form of composting the very high temperatures attained in this process would appear to result in some nitrogen loss. This may however be controlled by turning the pile at more frequent intervals, but implies greater labour input.

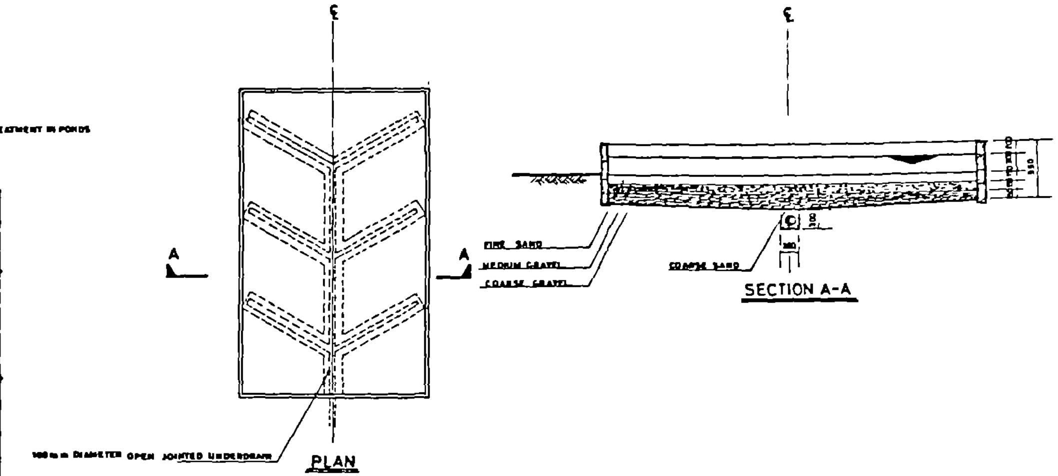
The chinese system of composting is perhaps the best form of non-mechanized process control available. This method however has the disadvantage of requiring a clay cover which further increase the steps involved in composting. It is nonetheless a remarkable method well suited to the needs of Orangi.

The force aerated composting system is a simple method capable of handling very large daily refuse inputs with a minimum of effort. It does however possess one disadvantage with regard to its application in and around Orangi, in that it requires a very moderate, but reliable, power supply. Since power demands are limited, this may easily be obtained by the use of generators.

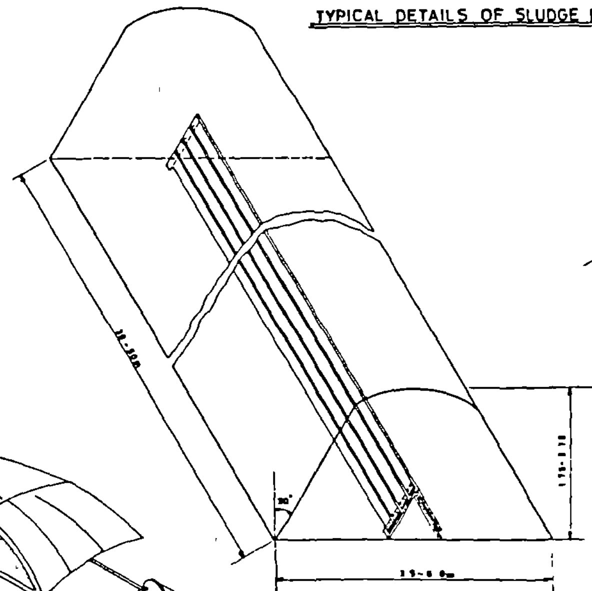
The need to provide a unified waste collection and disposal system with the maximum possible impact in improving the present day unhygienic conditions leads to the recommendations that the immediate commisioning of an integrated sludge drying and composting plant receives priority consideration. Sludge collected by suction tankers may first be dried to a desired moisture content and then mixed with the raw refuse before adding water to correct for moisture and subsequent stocking in piles. A schematic layout of such a plant is presented in Drawing No. 4. Design calculations leading to the determination of suitable dimensions for such a plant are presented in Appendix-E. As may be seen from these calculations it is hardly necessary to dry the sludge prior to mixing the compost feed. However, for aesthetical reasons, and the need to protect the surrounding areas from possible odour nuisance, the adoption of sludge drying has been recommended. A daily dry compost production of 55 tonnes would be obtained from such a plant.



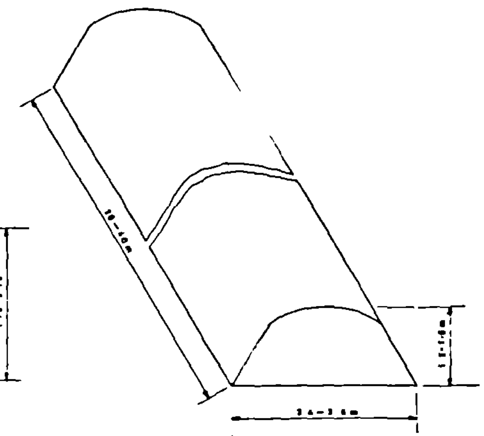
SCHEMATIC LAYOUT OF INTEGRATED SLUDGE DRYING AND COMPOSTING FACILITIES



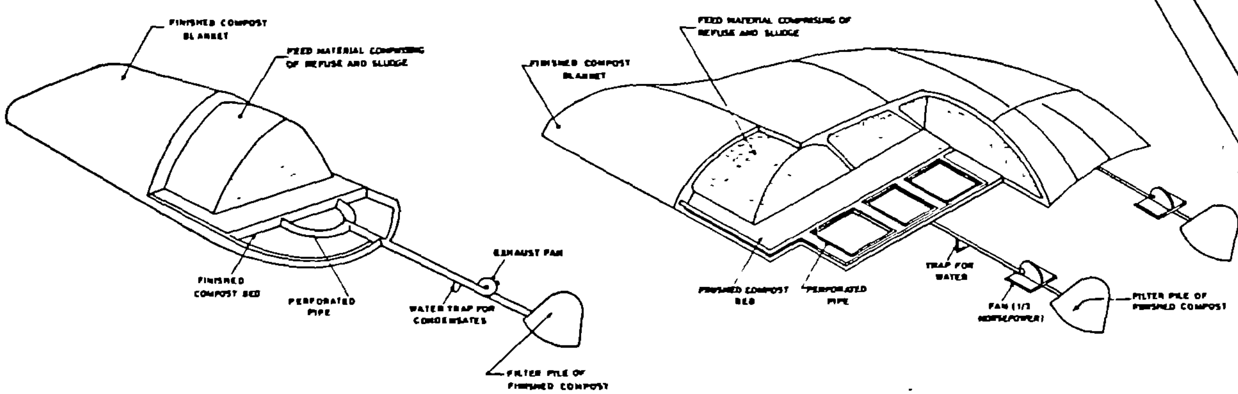
TYPICAL DETAILS OF SLUDGE DRYING BED



MACHANICALLY STACKED WINDROW



MANUALLY STACKED WINDROW



LAYOUTS OF FORCE AERATED COMPOSTING SYSTEM

BCCI-COP

SOLID WASTE MANAGMENT IN ORANGI

DETAILS OF INTEGRATED SLUDGE DRYING AND REFUSE COMPOSTING PLANT

SCALE	DATE	DRG. NO	
NOT TO SCALE	NOV 1984	04	

A total daily production of 52 m^3 of wet sludge is expected to be generated in Orangi. Assuming each suction tanker is capable of making four trips each day, two 6 m^3 suction tankers would be capable of servicing the whole of the project area. While the above integrated plant would arrest the indiscriminate disposal of sludge within Orangi, unless nightsoil collection depots are created and the nightsoil treated adequately the haphazard disposal of nightsoil in and around the area will continue. The diffusion of simple composting techniques, as those tried and tested in the present study, amongst those employed in collecting and disposing of nightsoil will have a very marked impact in ameliorating the present conditions. The adoption of nightsoil composting may be promoted by the Community Development Project through careful instruction of nightsoil collectors in the various composting techniques.

The technique to be applied in composting Orangi refuse would be dependent on factors such as availability of services such as water and power. It is however recommended that the force aerated pile system be adopted. The power demands of such a plant may easily be met with an on-site generator installation. While it is recommended that compost feed be composed of refuse and dry sludge the latter may also be easily replaced by animal manure, especially chicken wastes, consisting of 10 percent by weight of refuse. The many chicken farm distributed throughout, and on the periphery of the project area would provide an ideal source. The handling of drysludge is indeed very common in Karachi where dried digested sludge from the two trickling filter sewage treatment works are utilized extensively in the creation of green areas within the city.

7.4.1 Site For Composting

Since aerobic composting is a relatively odour-free process there is no need to install compost plants at great distances away from habitation. However, the incorporation of sludge drying facilities would demand more discretion in selecting appropriate sites. The composting technique adopted by the executing agency would, to a great deal, establish the area required for the plant. Initially a 2 hectare site would prove adequate for the recommended integrated plant, however, scope must be provided for its future expansion to meet future refuse generation. The site selected should, by necessity, have access to some form of non-saline water supply and preferably be supplied with adequate power.

It is recommended that a site be selected to the west of Orangi in such a way that the collection vehicles could move away from the built up area to surrounding uninhabited areas on the periphary. A site so located would ensure the minimum possible traffic congestion in the area. It will however be necessary to arrange for the development of access to such a site. It is likely that the creation of such access could lead to the continured expansion of Orangi along its path and in this context it is recommended that due consideration be given to future land use in that area.

7.4.2 Composting Equipment

As ascertained by the pilot scale composting investigations carried out at PCSIR, there is, at present, little need to provide equipment such as shredders and pulverizers prior to mixing the compost feed and stacking in piles. Initial shredding of the refuse would however speed-up the composting process. Dust control equipment would be required where shredding is adopted. Initially however, it is recommended that no shredding be undertaken especially since it is unlikely that the composting site will be supplied with electricity.

Compost feed piles may either be turned manually or by a front end loader. On average a single man may be expected to turn 5 tonnes/day and a front-end loader 120 tonnes/day. The comparative costs of 24 men against 1 loader prevails. Clearly while the purchase of a loader implies high initial capital outlay, manual operation implies continued high operating costs. Clearly financial limitations of the executing agency would determine the most suitable option. It is however recommended that a $2m^3$ bucket capacity, 60HP front-end loader mounted on rubber tyres be purchased and it is expected that capital recovery would be effective after approximately 2 years.

In preparing the compost feed some form of mixing is initially necessary. This once again may be undertaken manually or more suitably by means of a mini-tractor fitted with earth tilling equipment. Such a tractor fitted with a trailer may also be used to transport, within the site, various materials such as stones, metals etc., removed from the green compost. The propsoed tractor and tiller equipment are illustred in Figure **7.1.**

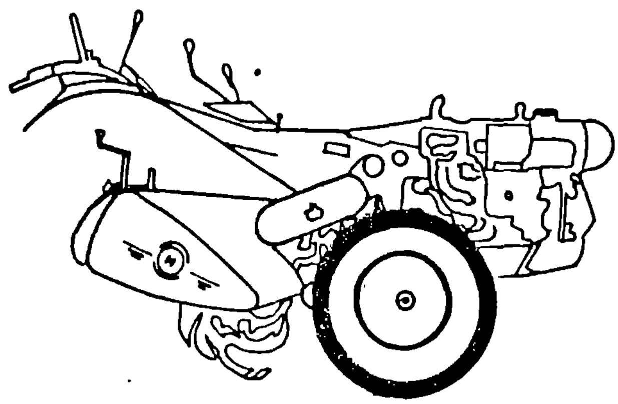


FIGURE 7.1 - PROPOSED TRACTOR EQUIPMENT FOR COMPOSTING PLANT

Finally some from of screening would be necessary after the feed has stabilized. Given the large daily output it is recommended that this be achieved by means of a mechanical screen. Green compost obtained after composting should initially be dischraged into a hopper which in turn would feed a slow moving (5m per minute) conveyor belt and the non-decomposed materials such as plastics, paper, glass, cloth and metals removed by labourers standing on either side of the conveyor belt. The sorted material is then screened prior to being placed in storage for maturing. Large organic materials, partially decomposed may be recycled. The thickness of the material on the belt should not exceed 15 cms to enable handpicking by labourers provided with hand gloves and other protective equipment. The removed materials will be stored separately so that they may be recycled.

Although the removal of non-decomposable materials may be performed prior to mixing the compost feed and placing in piles, the advantage in these materials become prominent amongst the stabilized black organic mass and are hence easily spotted for removal. An 8 hour storage capacity for the hopper would prove adequate.

A building would be required at the composting site which must provide for the following functions:

- Office;
- Laboratory;
- Workshop; and
- Store.

A weighbridge and instrumentation house which could also serve as the watchmans quarters is also required at the enterance to the site.

7.4.3 Summary of Equipment Required for Composting

Equipment required for composting utilizing force aerated techniques is summarized below:

TYPE OF EQUIPMENT	SPECIFICATION
1. Front-end loader	Rubebr wheeled, 2m^3 bucket capacity, 60 HP.
2. Mixing equipment	
a) Tractor and tiller	Two wheeled, 12 HP
b) Trailer	2.0m x 1.2m x 0.5m
3. Buildings	
a) Office	100 square metre
b) Laboratory	100 square metre
c) Workshop	150 square metre
d) Store	50 square metre
e) Weighbridge	50 square metre
f) Hopper	6m x 10m x 2m deep.
4. Sludge Drying Beds	10 No. 10.0m x 17.5m area.
5. Mixing and composting pad	4500 square metre.
6. Land	2.0 hecares.
7. Screens	
a) Trommel	1 No. 9 - 12.5mm openings
b) Shaker	1 No. 9 - 12.5mm openings

8.	Blower-fans	20 No. 1/3 hp; 220V, 22-23cm axial vane, centigugal fan; 3500 rpm, 10 cu.m per minute at 10cm static pressure.
9.	G.I Pipe Grids	1250m - 100mm diameter.
10.	Timers	1 No. 4 hr, 220V with 2 minute intervals.
11.	Thermocouple	60 No. potentiometer and thermocouple wire. Range 0 - 100°c.
12.	Conveyor belt	1 No. 10m long, 5m per minute.
13.	Steel containers with castor wheels	5 No. 1.5m^3 capacity with removable side panel.
14.	Weighbridge and Instrumentation	For a maximum total load of 10 tonnes.
15.	Generator	1 No. 10KW Hr - 3 phase.

7.4.4 Labour Requirements for Composting

The following skilled and unskilled labour inputs would be essential for the effective operation of the proposed compost plant.

Drivers	2 No.
Mixing labourers	4 No.
Sorting labourers	4 No.
Stacking labourers	2 No.
Storting and recycling labourers	2 Nc.
Watchmen	2 Nc.
Mechanic	1 No.
Supervisor	1 No.
Electrician	1 No.

7.5 Refuse Disposal In Low Density Peripheral Areas

While every attempt must be made to service all domestic premises within the project area, it is likely however that scattered residences along the periphary of the project area cannot be economically served. In such cases it is recommended that an on-site disposal pit be constructed of the type illustrated in Figure 7.2 be promoted to cater to these areas. When the first pit becomes full a second may be commissioned

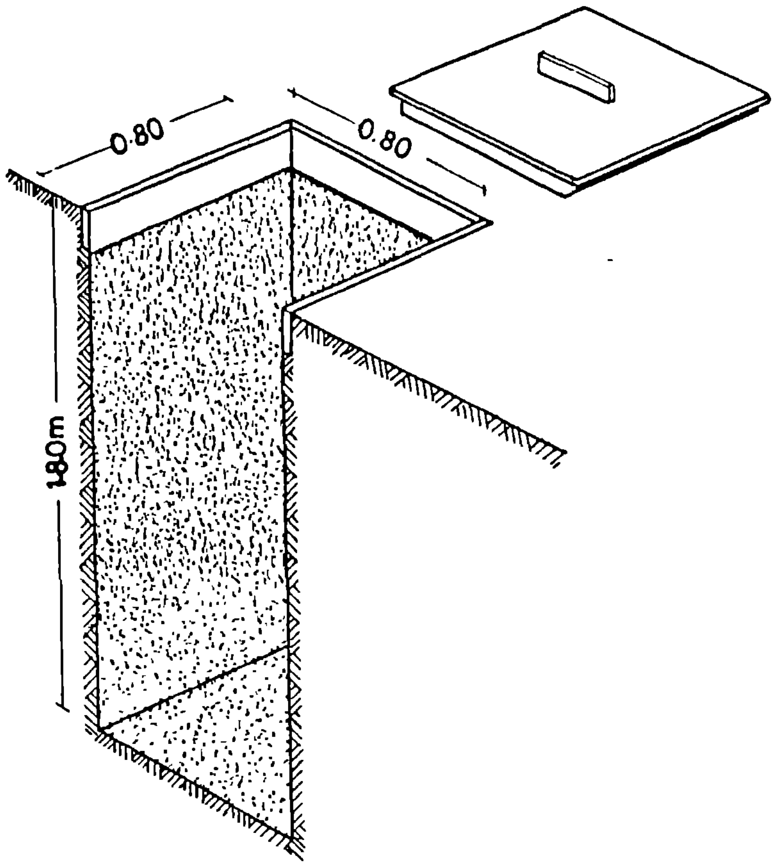


FIGURE 7.2 ON-SITE REFUSE DISPOSAL FOR LOW DENSITY SCATTERED DWELLINGS

7.6 Refuse From Health Clinics

Refuse generated from health clinics and small hospitals in the area must be given special consideration since they are likely to be contaminated with disease causing organisms. The safest disposal technique for such institutions is the use of simple low-cost incinerators. Details of one such incinerator is illustrated in Figure 7.3 A pit may be provided for burying the residue after incineration which is likely to include needless and glassware. After births produced from maternity clinics and home deliveries must receive adequate disposal. Burial is the most common means of disposal and a systematic and sequential manner in which this may be achieved is presnted in Figure 7.4.

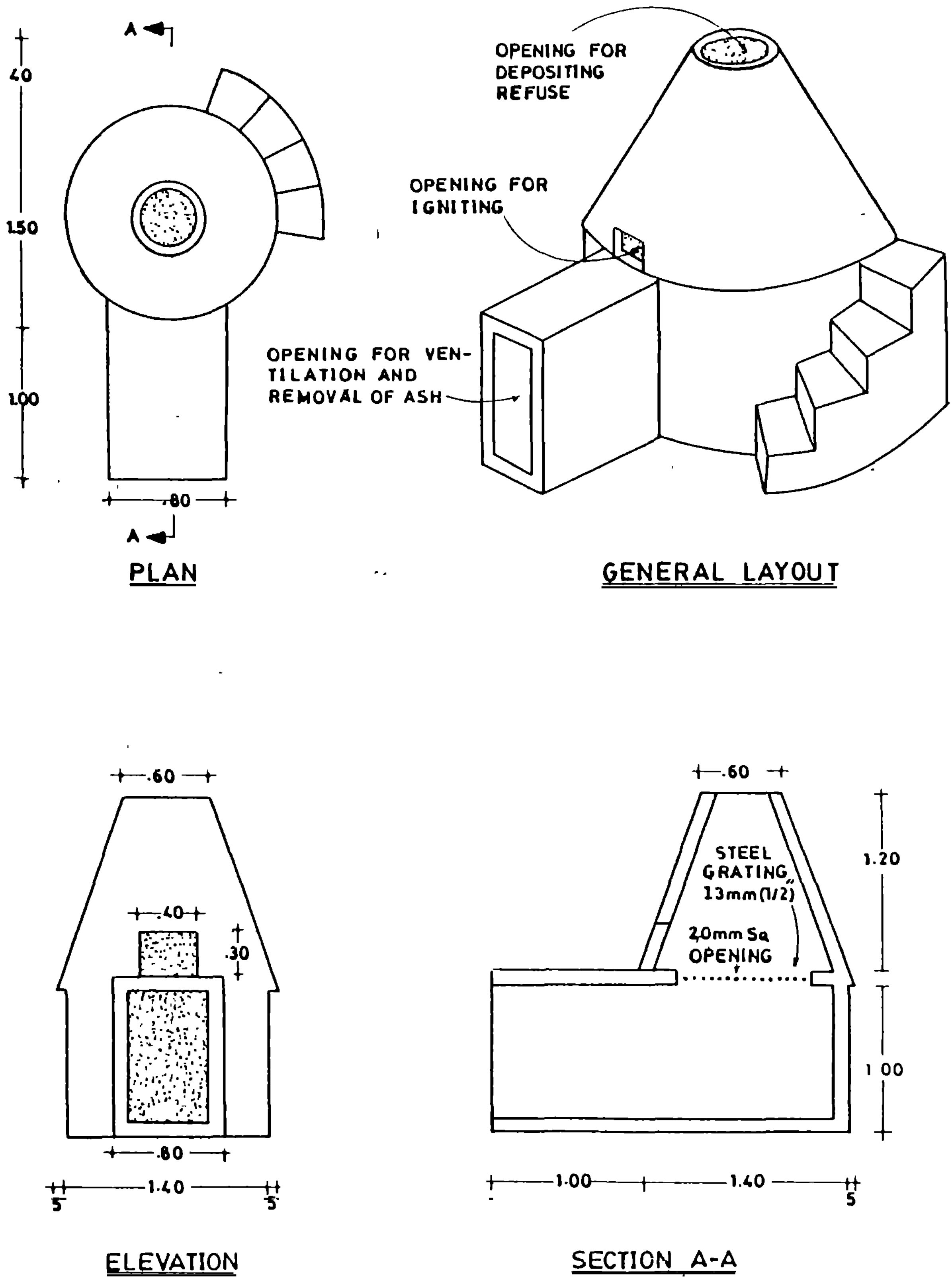


FIGURE 7.3 - SIMPLIFIED INCINERATOR FOR SMALL HEALTH CENTRES

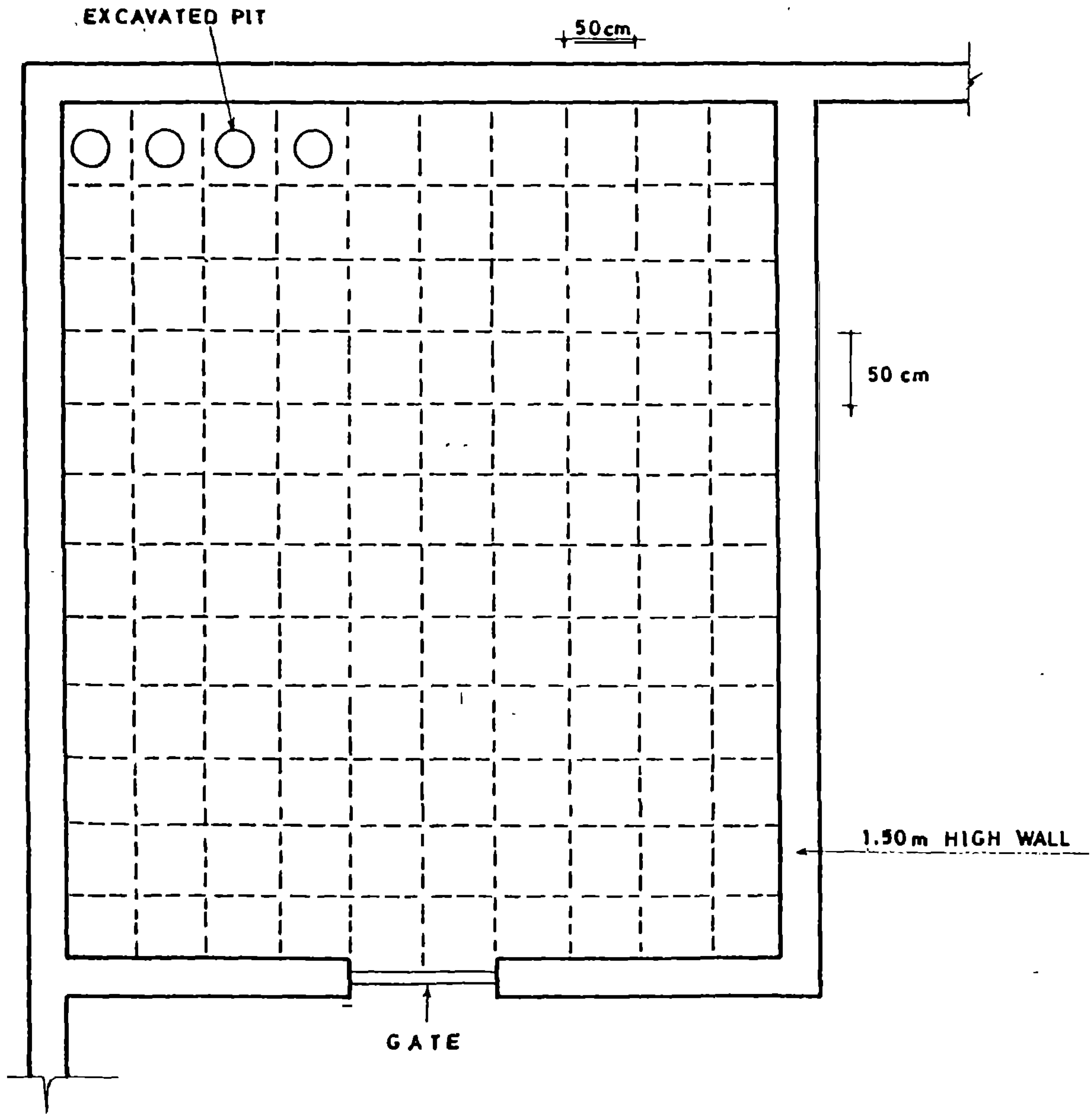


FIGURE 7.4 - SITE LAYOUT FOR NATAL WASTE DISPOSAL

8.0 ORGANIZATION AND MANAGEMENT OF THE SERVICE

8.1 General

Refuse collection and disposal service unless efficiently operated and managed can incur unnecessary and heavy demands on limited finances. It is considered that the most important action to improve the service is to create a competent organization and staff structure to manage the service. It should be emphasized that in the same way that water supply and sanitation are services designed to improve and safeguard public health, so is refuse collection and disposal. This does not mean that the skill required to operate these services is exclusively that of Environmental Health. It requires a complex set of multi-disciplinary skills including elements of civil engineering, mechanical engineering, chemisty, biology transport organization and economics. The service is, and must at present remain, labour-intensive and the critical factor in efficient organization of such a service is the quality of management.

8.2 Present Day Solid Waste Management Structure

The present day organization of refuse disposal in Pakistan follows the British system established for towns of 50000 population and less. In brief, the responsibility of refuse disposal under this system is entrusted with the medical officer of health, and the public health inspectors or santiary officers who manage solid waste amongst other duties such as the control of epidemics, mosquitos food production, slaughterhouses and the discharges of offensive trade wastes; public health education; building regulations and planning; immunization; sewage and nightsoil disposal; and meat inspection. Hence it is not surprising that they are only able to devote a very little attention to solid waste disposal. Further such a structure is completely out of context when applied to a large metropolis such as Karachi. Many international consultants observing the shortcomings of the present day system have recommended the institutionalization of a special department exclusively for providing the service of refuse disposal 1/. It is hoped that their proposals would be adopted.

1/ Tollemache, T., "Assignment Report Solid Waste Management in Oman, Pakistan and Sudan", World Health Oraganization, November, 1983.

Jackson, D.W., "Soild Waste Management Component", Karachi Special Development Programme, Planning and Development Division, Ministry of Planning and Development, Karachi, September, 1984.

It is considered important that the department should be concerned solely with refuse collection and disposal and similarly its staff should not have other duties. For success there must be a single minded application of various skills to create and maintain a sound service. This can in no way be achieved by officers who can devote only part of their time to the job.

8.3 Staff Structure and Job Evaluation

The hierarchy in the soild waste department will no doubt be established with the advent of the anticipated institutional reforms. However, in making functionally efficient the proposals contained in the present document the following structure is recommended. Each constituency area may be considered as a zone and each of the six zones be under the charge of a zonal supervisor whose duties would be to ensure the day to day effective operation of collection and street cleansing services. All six zones would be controlled by a single Zonal Manager whose responsibility would be the coordination of all efforts in refuse collection and disposal from all six zones.

Each zonal supervisor shall be responsible for all collection labourers and sweepers in his zone. At the disposal end of the operation a single refuse disposal supervisor will be necessary to instruct and supervise all labour on site and ensure adequate quality control. All officers mentioned must be mobile to execute their duties and transport in the form of motorcycles must be provided to them.

8.4 Manpower

Proper vehicles, plant and equipment will enable an effective service to be provided with less workpeople and it is therefore essential to build up and retain a satisfactory and reliable workforce which should be properly instructed in the new methods.

Improved methods and tools will enable productivity to be obtained with less workpeople and it should be possible to pay wages comparable with those paid for similar work elsewhere in the city without seriously increasing total labour costs.

It is estimated that the following workpeople will be needed initially, provided the vehicles requirement detailed in Table 6.2 are supplied and that able - bodied and satisfactory employees are engaged:

Collection:	1	Manager
	5	Zonal Supervisors
	75	Moped Drivers/Refuse Collectors
	5	Collection Vehicle Drivers
	5	Collection Vehicel Assistants
	30	Street Sweepers
	121	
Composting and Disposal:	2	Drivers
	12	Labourers
	2	Watchmen
	1	Mechanic
	1	Electrician
	1	Process Supervisor
	19	

8.5 Centralized Maintenance and Garaging Facilities

The successful operation of the refuse collection service will require a central depot for the servicing and garaging of vehicles, storage of equipment and the administration of the service personnel.

It is recommended that this facility be provided at the composting plant where first line maintenance and servicing may be undertaken. Major overhaul and repair work however is best carried out at a centralized facility for the whole city. Provision would be made for vehicle inspection and routine servicing and maintenance. Washing of vehicles at frequent intervals will also be necessary. The provision of an adequate cleaning area at the compost plant site is therefore important. A servicing schedule must be established for all plant and vehicles for routine inspection, cleansing and maintenance.

9.0 ESTIMATED COST OF PROPOSED SERVICE AND FINANCIAL APPRAISAL

9.1 General

The capital cost of the proposed refuse collection system are estimated assuming full implementation such that items of equipment as containers, three-wheeled mopeds, roll-off tippers are all provided. Cost estimates have been prepared on local prices for basic materials, labour and plant and represent the approximate amounts which would be payable for the required civil, electrical and mechanical contracts at the present date Details of the cost estimates are presented in Appendix-F. All the estimates are exclusive of engineering fees and land costs and no allowance has been made for the effects of future price inflation.

9.2 Summary of Capital and Operating Cost

The overall capital and operating cost of the proposed refuse collection and processing system are as follows:

Total capital cost of refuse collection equipment	=	Rs.3,300,000
Total capital cost of compost plant		
- Plant and Equipemnt	=	Rs.1,545,300
- Civil works	=	Rs.1,500,000
- Total	=	Rs.3,045,300
Total annual operating cost of collection system	=	Rs.1,813,680
Total annual operating cost of compost plant	=	Rs. 814,768

9.3 Financial Appraisal

Ideally it would be necessary to undertake an economic analysis to ascertain the cost implication to the national economy of providing this form of refuse service. However, such an analysis requires extensive knowledge of macro economic parameters such as shadow prices, opportunity cost of capital and some means for assessing the agri-cultrual nutriative value of the final product. The inclusion, in such an analysis of non-tangible benefits such as those derived from improved health resulting from the solid waste management intervention would also be necessary. However, such benefits are indeed extremely difficult to quantify and no satisfactory method has yet been evolved. Hence, the analysis presented herein is limited to financial considerations alone.

The following parameters were adopted in the analysis:

amortization rate	=	8%
life of plant and machinery	=	5 years
life of civil works	=	20 years

Details of the financial analysis are presented in Appendix-F. Following is a summary of the results of the analysis.

Total overall capital cost of collection and disposal per house	=	Rs.150.7
Total overall annual operating cost of collection and disposal system per house	=	Rs.62.4
Total annuetized capital cost per tonne of compost produced	=	Rs.82.6
Total annuetized operatin cost per tonne of compost produced	=	Rs.159.3
Total cost of producing compost	=	Rs.241.8/tonne

No market survey was conducted in order to assess the marketability of the compost as a plant fertilizer. However, discussions conducted with a private composting company in the process of being set up in North Karachi seem to indicate that there is a true potential demand for the product. Values as high as Rs.750 per tonne were quoted as being attainable. Markets likely to yield such high returns were thought to be based in the middle-east; at present large quantities of animal wastes with similar fertilizing properties are being exported to these markets at similar prices.

Clearly a detailed market survey must precede the adoption of proposals presented herein. It is however encouraging that it does present some potential for recovering some, if not all, capital and operating outlays. These possibilities introduce a further alternative when considering possible means of executing solid waste collection and disposal. This alternative is the possibility of attracting private bodies to implement adequate solid waste management in the study area which is the prime concern of the present community development project.

While all costs have been computed in relation to providing a comprehensive refuse disposal service in the project area, the extension of the service to other parts of Orangi and Karachi could bring about further cost reductions as a consequence of the resulting economies in scale. The integration of refuse and sludge disposal in a single co-ordinated operation will have a marked impact on the health of the Orangi Community.

The financial appraisal undertaken revealed that the cost of implementing the recommended service, without taking into account any cost recovery from the sale of compost, is affordable by the community given their present socio-economic status.

Total capital cost of the proposed system	=	Rs.150.7 per house
Total monthly operating cost of the proposed system	=	Rs.5.2 per house.
Total annual cost per household (capital and operating costs)	TACH=	Rs.94.8

The second possible means by which the proposed scheme may be implemented is on a self-help basis where all capital expenditures are met by the community and a monthly or annual tariff charged for its operation. Clearly, as benefits will no doubt accrue from the scale of the processed refuse these must be passed on to the community. These benefits will no doubt obviate the need to pay recuring tariff for the service. The possibility of reducing the initial capital outlay to be obtained from the community may also be considered by the executing agency, in anticipation of future benefits. The community development project in these circumstances could act as a catalyst in organizing community support for the scheme and liaise with the executing agency in bringing about successful form to these proposals. The project may also consider becoming the executing agency in which case maximum benefit may be provided to the community who would also be ensured of an efficient service.

A third cost recovery mechanism may be created by composing a revolving fund by which the local authority currently responsible for the service, namely the Karachi Metropolitan Corporation, could implement the service which it could expand to other areas following receipts of proceedings from the sale of compost. Adequate funds to ensure the detailed implementation of the scheme and sustained operation must be guaranteed and a market for the product confirmed.

As stated at the start of the present section, the major benefits of producing compost cannot be quantified. The improvment in health in removing all forms of human created wastes, from the community, although considerable cannot be adequately measured. Similarly the value of compost in improving the local soil for agricultrual production would be great. This is particularly true for the Sind region where although the soil is fertile lack of water and the ability to retain moisture are its basic deficiencies. The addition of chemical fertilizers in this case would be of little use and is likely to lead to other ecological problems. Compost however possess the ability to condition the soil and improve its moisture retaining properties and can also act as a valuable fertilizer especially if supplemented with chemical fertilizers. It is pershaps the one single factor which can provide an inexpesnive solution to the problem of desertification, currently a major preoccupation of the Government. Even when exported to other countries aware of its benefical properties, it represents a valuable asset in generating foreign exchange.

While this document has concentration in recommending means by which a single excuting agency may effectively collect solid wastes and process them to make compost, these recommendations were made in the interest of providing an intergrated, comprehensive service throughout the project area. It is however possible that the project area can alternatively be served by many private individuals, as an extention to the present day resource recovery practice, using more simpler transport systems such as donkey carts and bicycle wheeled push carts. Simpler, less energy demanding composting techniques tested during the course of the present study may also be adopted. The present project under such circumstances could act as the cohesive force in bringing together these individuals and providing the necessary training to diffuse the tested composting techniques and provide general orientation, along the guidelines established in the present document, to improve soild waste management in Orangi.

9.4 Other Benefits

Additional benefits may be derived from the recycling of other materials present in the refuse. The more important of these are given below together with the average percentages in which they re found:

- paper 4%
- plastics 1.5%
- metals 0.35%

From the recycle value of these material given in Table 4.2 and expected refuse generation rates given in Table 3.2, the following daily income from recycling may be expected.

Paper	=	2% (after drying) x 78 x Rs.2000	=	Rs.3120
Plastic	=	1.5% x 78 x Rs.5000	=	Rs.5850
Metals	=	0.35% x 78 x Rs.6000	=	Rs.1638
			TOTAL	**Rs.10,608**

The implies an annual income of over Rs.3.1 million or an equivalent annual per household income of approximately Rs.75. This value is only Rs.20 below the total annual cost per household (TACH) of providing the service and underlines the lucrative importance of resource recovery.

10.0 RECOMMENDATIONS AND CONCLUSIONS

10.1 Immediate Action

The full proposal for the new refuse collection service and the medium and long term refuse disposal will require time before implementation. Finance will need to be allocated and vehicles and plant acquired, staff recruitment will be needed.

Discussions must be initiated immediately with KMC and interested private bodies to reach concordance as to the most suitable means by which the proposals suggested in the present documents may be implemented. Due consideration must also be given to the possible organizing of local "Cabadiwals" 1/ who may, under the close coordination of the present project, extend their present day practice to recover the organic fraction of the refuse too.

Initiate the production and availability to the community of the improved domestic storage containers referred to in Section 6.2.1.

As an extension of the user awareness programme undertaken concomitant with the project sanitary intervention, and through other social contacts, promote and instill in the community the need for adequate refuse disposal as an integral part of reinforcing and furthering the benefits of the sanitary intervention and providing a safe environment.

Diffuse the simple composting techniques tested during the study amongst those currently employed in collecting and disposing of nightsoil as a means of providing adequate treatment to the nightsoil collected and providing an environmentally safe and stable fertilizer.

Undertake extensive market surveys to assess the demand and possible returns from the production of compost.

10.2 Action for Full Implementation of New Service

The actions outlined in Section 10.1 above will allow time in which to establish the authroity who will be entrusted with the task of

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1/ Used Material Merchants.

refuse disposal in the project area and specify their duties and responsibilities. Depending on these institutional arrangements, it may be necessary to consider the phased implementation of the scheme giving priority to high density areas.

Details of recommendations are given in Appendix G; the salient points of these recommendations are as follows:

i) The implementation of a planned, integrated and comprehensive system of refuse and sludge collection and their processing by means of force aerated techniques to produce compost.

ii) The technical and administrative organization and staff be appointed to oversee the implementation of the scheme.

iii) Action be taken to acquire the necessary suitable vehicles and plant and a site for waste processing.

iv) Action be taken to prepare and provide necessary utilities and equipment for the compost plant and vehicle depot.

v) Professional advice be obtained to assist, by way of vehicle and equipment specifications, buildings and constructional works designs, for implementation of the recomended and agreed proposals and in connection with the future operation of the service.

vi) Provide facilities for the manual reclamation of paper, plastics and metals.

10.3 Conclusions

The following conclusions may be drawn from the investigations conducted during the course of this study.

1. It is possible to offer a comprehensive refuse collection and disposal service for the project area which is well within the limits of affordability of the community to be executed on a self-help basis.

2. Orangi refuse is eminently suited for composting and offers great potential for all forms of resource recovery.

3. The diffusion of the simple composting techniques developed and the adoption of an integrated sludge dry and composting facility will have a very positive impact on the environment and the health of the commmunity.

4. If properly coordinated and operated, the refuse service which seeks to produce compost as an end product can be self financing.

APPENDIX 'A' - SAMPLE DOMESTIC REFUSE COLLECTION AND DISPOSAL QUESTIONAIRRE

REFUSE COLLECTION AND DESPOSAL QUESTIONAIREE

Mohallah: House No:

1. How many persons reside in this house ? ____________

2. Where do you Store your garbage ?

   ☐ In a pile on the Floor ☐ 18 Litres Oil Tin ☐ G.I. Bucket
   ☐ Plastic Bucket ☐ Paper or Plastic Bag ☐ Other (Specify)________

3. A pproximate dimensions of container ____________

4. How much refuse do you collect in a day ?

   ☐ $\frac{1}{4}$ Container ☐ $\frac{1}{4}$ Container ☐ $\frac{1}{3}$ Container ☐ $\frac{1}{2}$ Container
   ☐ $\frac{2}{3}$ Container ☐ $\frac{3}{4}$ Container ☐ Full Container ☐ Other (Specify)____

5. How often is your refuse removed for disposal.

   ☐ Once a day ☐ Once in 2 days ☐ Once in 3 days
   ☐ Once in 4 days ☐ Once a week ☐ Other (Specify) ________

6. Who removes the refuse for disposal ?

   ☐ House Holder ☐ Sweepers ☐ Other (Specify) ________

7. How much do you pay your Sweeper each month for removing refuse Rs.________

8. Where do you dump your refuse ?

   ☐ Open Plot ☐ Nala ☐ Front of House
   ☐ Road ☐ K.M.C. Tip ☐ Other (Specify) ________

9. What happens to the dumped refuse ?

   ☐ Stays there ☐ Removed by K.M.C. ☐ Burnt ☐ Other (Specify)____

10. Do you retain any material for sale, if so which ?

    ☐ No ☐ Paper ☐ Roti ☐ Plastic ☐ Glass
    ☐ Metals ☐ Chapals ☐ Cloth ☐ Foodwastes ☐ Other (Specify) ____

APPENDIX B – CHARACTERISTICS OF KARACHI REFUSE

TABLE B1 - PHYSICAL ANALYSES OF KARACHI REFUSE

Sample No.	Location	Wt. of solid waste (Kg.)	Moisture (%)	Garbage (%)	Dust (%)	Stones (%)	Paper and card board (%)	Textile pieces, rope & cloth (%)	Bone, poultry waste etc. (%)	Metals (tin, brass, iron etc.) (%)	Glass (%)	Crockery pots, earthen ware etc. (%)	Marble lime, chalk, cement blocks etc. (%)	Leather rubber and old shoe (%)	Poly thene and plas-tics (%)	Peels of fruits vegeta-ble etc. (%)
1.	Near KMC Treatment Plant Mahmoodabad.	320.00 171.77	46.32	2.99	9.47	5.79	6.35	8.0	1.25	0.34	0.5	2.41	0.22	1.32	1.67	2.51
2.	Block-B Sindhi Muslim Society Shahra-e-Faisal	110.00 77.21	29.8	1.88	16.9	2.63	6.09	5.59	1.09	0.136	0.04	0.26	Nil	1.72	1.27	2.09
3.	Opp. Society Complaint Centre Shahra-e-Quaideen	96.4 53.0	45.02	1.08	0.88	0.05	7.15	10.21	0 41	0.15	0.07	0.85	Nil	0.82	2.48	2.74
4.	Dhoraji Colony Market	99.20 41.45	58.21	0.72	6.43	3.27	2.62	2.72	0.65	Nil	Nil	Nil	Nil	Nil	0.65	1.05
5.	Near Market Delhi Socagran Society	104.40 30.79	70.5	0.02	0.12	0.76	2.82	2.84	0.71	0.04	0.12	3.51	Nil	Nil	1.04	3.78
6.	Dhoraji Colony near Dhoraji Chowrangi	56.0 43.6	22.09	4.66	34.17	14.1	2.23	3.88	0.71	0.08	0.26	1.64	0.61	0.53	0.45	4.55
7.	Tariq Road Market PECHS	66.8 40.14	39.91	1.24	11.84	17.73	2.02	6.39	0.14	0.07	0.33	0.52	0.04	1.12	0.25	3.59
8.	Near Brazil Primary School PECHS	32.08 20.7	35.95	5.04	10.13	3.97	3.42	7.94	0.46	0.23	Nil	Nil	Nil	0.15	1.4	6.23
9.	Mohammad Ali Society, Fatima Jinnah Road, Kar.	105.6 21.81	79.34	0.36	7.0	2.08	1.55	1.08	0.47	0.07	Nil	Nil	0.66	0.04	0.23	4.66
10.	Kokni Society, Off Shaheed-e-Millat.	54.88 24.90	54.62	2.05	6.15	2.01	2.09	4.91	0.54	0.09	0.4	3.08	Nil	0.86	0.54	8.38

Sample No	Location	Wt of solid waste (Kg.)	Moisture (%)	Garbage (%)	Dust (%)	Stones (%)	Paper and card board (%)	Textile pieces, rope & cloth (%)	Bone, poultry waste etc. (%)	Metals (tin, bress, iron etc. (%)	Glass (%)	Crockery pots, earthen ware etc. (%)	Marble lime, chalk, cement blocks etc. (%)	Leather rubber and old shoe (%)	Poly thene and plas-tics (%)	Peels of fruits vegeta-ble etc. (%)
11.	Amber Cinema, Bahadurabad Chowrangi	51.28 29.36	42.73	6.62	11.81	2.82	4.19	13.94	0.09	0.53	0.48	Nil	Nil	Nil	0.39	2.04
12.	Khudad Colony	40.68	16.29	10.4	12.7	5.83	4.17	14.99	0.67	0.18	0.12	1.72	Nil	7.49	1.22	16.59
13.	Lal Market, New Karachi	47.98 36.57	23.77	11.2	17.04	10.31	4.68	14.38	0.93	0.2	0.2	3.69	Nil	1.25	0.62	0.93
14	Child Care Centre Pir Colony	80.56 43 38	46.14	7.82	16.19	5,15	3,78	8.93	0.31	0.37	0.37	1.05	Nil	3.66	0.74	0.86
15.	Near Shomalia Appartments, Gulshane Iqbal	66.48	62.88	4.28	10.01	0.9	2.25	3.45	0.56	0.22	0.86	1.11	Nil	0.3	1.42	4.58
16.	Noorani Masjid, Aliabad, FB Area	71.54	24.79	8.03	24.84	16.8	0.55	4.33	2.09	0.23	0.25	1.38	Nil	0.06	0.13	[illegible]
17.	Nusrat Bhutto Colony, North Nazimabad	74.76	30.41	14.31	30.0	4.34	1.13	9.43	0.69	0.3	0.2	0.86	Nil	0.46	0.50	0.2
18.	Liaquatabad Market	62.16 31.4	49.48	3.73	14.03	3.13	5.63	7.48	0.44	0.8	Nil	4.46	Nil	2.25	0.64	[illegible]
19.	New Chali	61.48	42.9	5.1	13.11	4.1	6.5	8.53	0.2	0.56	1.78	1.21	Nil	0.85	1.95	2.76
20.	Kharadar	117.2 59.65	49.1	6.88	13.97	5.93	3.96	2.94	0.59	0.27	0.46	2.17	Nil	0.76	0.89	3.25

SOURCE: Beg, M.A.A., Mahmood, S.N., and Naeem, S., "Environmental Problems Part-I, - Solid Wastes, Their Evaluation", Pakistan Council for Scientific and Industrial Research(PCSIR), Karachi 1984.

TABLE B2 - PHYSICO-CHEMICAL CHARACTERISTICS OF KARACHI REFUSE

Sample	Location	pH	Moisture (%)	Loss at 600°C (%)	Loss at 1000°C (%)	Ash (%)	Organic matter (%)	Organic Carbon (%)	Carbonate (%)	Nitrogen (%)	C/N ratio	C/N ratio
1.	Near KMC Treatment Plant	7.7	46.32	34.05	50.1	49.9	13.71	8.06	3.2	0.63	12.79	21.76
2.	Block-B, SMHS, Shahra-e-Faisal	7.9	29.8	29.76	48.28	51.72	17.09	10.09	4.3	0.53	18.96	32.24
3.	Opp.Society Complaint Centre, Shahra-e-Quaidin	7.8	45.02	46.12	60.32	39.68	20.75	12.20	4.5	0.76	16.05	27.3
4.	Dhoraji Colony Market	7.8	58.21	32.84	51.92	48.08	16.67	9.80	4.7	0.71	13.80	23.4
5.	Near Market Dehli Sodagran Society	7.7	70.5	49.78	66.32	33.68	24.0	14.11	4.6	0.32	44.09	75.0
6.	Dhoraji Colony near Dhoraji Chowrangi	7.6	22.09	30.52	45.51	54.49	17.37	10.21	4.5	0.44	23.2	39.47
7.	Tariq Road Market, PECHS	7.0	39.91	39.26	50.22	49.78	18.75	11.02	4.4	0.90	12.24	20.8
8.	Near Brazil Primary School PECHS	7.8	35.95	28.50	38.85	61.15	15.41	9.06	4.8	0.80	11.32	19.25
9.	Muhammad Ali Society, Fatima Jinnah Road	7.7	79.34	23.81	37.31	62.69	17.77	10.45	4.5	1.23	8.49	14.44
10.	Kokni Society, Off Shaheed-e-Millat Road	7.7	54.62	34.99	44.31	55.69	18.22	10.71	4.2	0.91	11.76	20.02
11.	Amber Cinema, Bahadurabad Chowrangi	6.6	42.73	32.50	46.94	53.06	12.28	7.22	5.1	0.6	12.0	20.46
12.	Khudadad Colony	6.9	16.29	20.76	39.08	60.92	14.61	8.59	4.6	0.61	14.08	23.95
13.	Lal Market, New Karachi	6.7	23.77	31.59	51.46	48.54	15.84	9.31	4.3	1.28	7.27	12.37
14.	Child Care Centre Pir Colony, Karachi	7.1	46.14	17.11	34.39	65.61	14.23	8.37	4.5	0.62	13.5	22.95
15.	Near Shomalia Apartments Gulshane Iqbal	6.2	62.88	36.94	51.63	48.37	37.45	22.02	3.9	1.24	17.75	30.2
16.	Noori Masjid, Aliabad F.B.Area Karachi.	7.1	24.79	19.83	36.91	63.09	13.69	8.05	4.5	0.47	17.12	29.12
17.	Nusrat Bhutto Colony North Nazimabad	6.1	30.41	26.69	43.78	56.22	22.18	13.04	4.9	0.74	17.62	29.97
18.	Liaquatabad Market	7.3	49.48	16.91	33.22	66.78	14.14	8.31	4.6	0.59	14.08	23.96
19.	New Chali	7.0	42.9	20.08	37.14	62.86	17.26	10.15	5.1	0.57	17.8	30.28
20.	Kharadar	6.6	49.1	25.06	40.97	59.03	16.67	9.80	4.8	0.48	20.4	34.72

SOURCE: Beg, M A.A., Mahmood, S.N., and Naeem, S., "Environmental Problems Part I - Solid Waste, Their Evaluation," Pakistan Council for Scientific and Industrial Research (PCSIR), Karachi 1984.

APPENDIX C - THE IMPORTANCE OF FLY CONTROL

The fly is one of the most prolific pests of man. More insecticides are used for its control than any other pest.

It can carry disease organisms causing typhoid, cholera, gastro-enteritis, diarrhoea, dysentery, trochoma, tuberculosis as well as intestinal worms and protazoa.

The housefly can only swallow liquid food and in order to feed on solid matter, it uses salvia (and regurgitated fluid from already digested food) in order to disolve the solid into a type of both which it sucks up through its proboscis.

In its breeding it goes through four stages, egg-larval-pupa-adult fly.

The fly requires certain conditions for the deposition the its eggs, and these include moist, fermenting or decomposing vegetable or organic matter. The female seeks out a suitable breeding site by sense of smell and deposits her eggs in such a way as to prevent drying out in the sun. The batches of eggs usually number 100 to 140 and an adult fly may lay several batches at intervals during her life.

The full life cycle from egg to adult depends on weather and temperature but can be as short as four days. In hot countries the fly will live about one month, in milder climates, upto three months.

The eggs quickly incubate and when hatched produce a small maggot or larvae which burrows into the food to avoid the light and to feed on the material. During the larval stage they remain below the surface, but if the surface is covered with inert material they will eventually move to just below the new surface, or they will migrate some distance away from the breeding site where they will also remain below the surface.

Here they form a pupa from which the live fly eventually emerges, this is a small bean shaped object upto 7mm long. Excavation of infested ground around dumps reveals, at about 50mm below the surface, considerable numbers of larvae and pupa. The number can be as high as 10,000 per square metre.

In due course the adult fly emerges and makes its way to the surface. Here it walks on the surface for some time until its wings are fully expanded and its air sacs are filled, whereupon it starts to fly. The adult fly can travel many kilometers from the breeding site.

When already infested material is buried and covered with clean material such as sand, the larvae hatch out and move either upwards or outwards where they pupate below the surface, eventually emerging as a live fly. If larvae are already present in the infested material when it is cove-ed, they pupate in the material, but the live fly when it emerges can penetrate upwards through very thick layers of material. It has been found that this has occurred through 45cm of hard packed and consolidated soil.

The main feature of the life of a fly is that it must have some time on the surface to develop before it can use its wings, and therefore treatment of the surface with an insecticide with a residual toxicity is necessary to effect complete control.

The most effective control measure is to prevent eggs being laid in the waste before it is collected. This is usually impossible to achieve completely. The covering of all waste containers can do much to reduce the problem. Open dumps which infest the ground, and the regular deposit of waste in the same places in the open, make the problem more difficult. All wastes should as far as possible be stored and conveyed in containers kept covered.

Frequent removal of waste from the containers to the disposal site is important, the actual frequency depends on the method of storage at the place of production of the waste, the method of collection and the climatic conditions. It is very important to keep refuse and waste off the ground to avoid larval infestation by migration.

Residues of waste in storage and in waste collection vehicles also encourage the deposit of eggs and later infestation of other waste placed in such containers or vehicles. For this reason it is essential that containers and vehicles be thoroughly and regularly emptied on each occassion and that they be washed and spinkled with lime at regular intervals

In composting refuse it is important that the mixed feed preparation and moisture adjustment be undertaken as quickly as possible in order to raise immediately the temperature which will ensure the destruction of eggs,larvae and pupa and also to prevent further egg laying in the uncovered mass. In windrow compostig it is essential to ensure that all sections of the pile, at one time or the other, comes in contact with a high temperature environment. In turning the pile it must be ensured that material on the external surface is placed in the middle of the new pile and the material originally in the middle is placed on the surface.

APPENDIX D - CODE OF PRACTICE FOR LANDFILL TIPPING OF WASTE

1. **Site**

Must be satisfactory in respect of:

1. Access from highway.
2. Non-liability to subsoil or other water contamination by percolates (leachate) from the waste.
3. Of suitable form and elevation to facilitate constructional tipping on terraces or layers or trenches.
4. Not liable to inundation or erosion by heavy run off of surface water
5. Not close to buildings or dwellings.
6. Within economic reach of collection area.
7. Provides available cover material.

2. **Site survey and operational plan.**

A proper survey and accurate operational plan should be made indicating levels and contours and potential source of cover material.

3. **Preliminary works.**

a) Cut-off drains and channels to be formed to divert surface water flows from the tipping area.

b) The site to be fenced against animals.

c) A suitable access road, formed to easy gradients to be provided between the highway and the tipping area.

4. **Working Method.**

The method of working to be either:

a) Cut and fill-trench; or

b) terrace or layer forms.

A working plan to be adopted and adhered to in operation.

ii) On level flat sites - the cut and fill method is used by excavating 1m deep over an area 30m wide and proceeding in length as tipping continues.

iii) On sloping sites the terrace system is used where a base terrace bank 2.5 to 3m high is formed to retain material tipping behind.

5. **Formation and control of tip.**

1. Tipping to be restricted to one area at a time.
2. The waste to be formed into a 2.5m thick layer immediately after it is tipped.
3. Material should be deposited at the base of the tip behind the bank and pushed into position by the mechanical shovel pushing upwards and running over it to form a sloping face.
4. The depth of the layer not to exceed 2.5m.
5. To permit settlement and completion of fermentation processes a period of three months should elapse before a further layer is added.
6. The width of tipping face should not exceed 20m at any time.
7. As tipping proceeds the sides and face should be consolidated to form gradients not steeper than 30° by driving the tractor up and down the sides and face.
8. The tipped material to be progressively covered with at least 15cm of moist material including sides and face and no waste shall be left exposed at the end of the working day.
9. Each layer of waste to have a surface slope sufficient to drain off heavy rainfall.
10. No material shall be burnt on or near the tip and any fire which occurs shall be immediately dug out and extinguished.
11. Large bulky and offensive waste to be buried at the foot of the tip and covered with other waste.
12. The site shall be always kept clean and tidy and no accumulations of any kind shall be permitted.
13. If the land is eventually to be used for agricutural purposes

the last 30cm in thickness shall consist of soil or previously fully composted wastes.

APPENDIX E - DESIGN CALCULATION FOR INTEGRATED SLUDGE DRYING AND COMPOSTING PLANT

a) **Feed characteristics without sludge drying.**

Total initial volume of raw refuse = 226m^3/day.

Total initial weight of raw refuse = 78 tonnes.

Assuming an annual sludge production rate = 40 litre/capita/yr and 300 working days per year

Total annual volume of sludge produced = $320{,}000 \times 0.04 \times \frac{365}{300}$ =15,537m^3/yr

Daily volume of shudge production = 52m^3.

Raw refuse - moisture content = 20%

- C/N ratio = 48

Digested wet sludge.

- moisture content = 85%
- C/N ratio = 9.
- volatile solids = 40%
- fixed solids = 60%
- specific gravity of digested solids. = S_s
- specificgravity of digested sludge = S_s

$$\frac{1}{S_s} = \frac{0.60}{2.50} + \frac{0.40}{1}$$

$$S_s = 1.56$$

$$\frac{1}{Sd_1} = \frac{0.15}{1.56} + \frac{0.85}{1}$$

$$Sd_1 = 1.06$$

Daily wet weight of sludge production = 52x1.06 = 55 tonnes.

C/N ratio of mixed feed:

78x48 + 55x9 = (78+55) x C/N feed.

C/N feed = 32

Moisture content of mixed feed:

78x0.20 + 55x0.85 = (78+55) m/c feed.

m/c feed = 47%

Supplementary water required to raise moisture content to 60 percent;

78x0.20+55x0.85+ add water x1 = (78+55+add water) x 0.6.

additional water = 44m^3

Note: C/N ratio and moisture content of feed within specified optimum ranges of 30 to 35 and 40 to 60 respectively.

b) **Feed characteristic after sludge drying.**

Digested dry sludge	-	moisture content	=	60%
	-	C/N ratio	=	9.
	-	volatile solids	=	40%
	-	fixed solids	=	60%
	-	specificgravity of dry digested shudge.	=	Sd_2

$$\frac{1}{Sd_2} = \frac{0.40}{1.56} + \frac{0.60}{1}$$

$$Sd_2 = 1.17$$

Initial total volume of sludge	=	52m^3
Initial weight of sludge	=	55 tonnes
Initial weight of water in sludge	=	0.85x55 = 47 tonnes
Initial weight of solids in sludge	=	0.15x55 = 8 tonnes.

Assumming no loss of solids :

8 = 0.4 x weight dry sludge

Weight of dry sludge d = 20 tonnes.

Weight of dry sludge = $\frac{20}{1.17}$ = 17m^3

Volume of water in sludge = 0.6x20 = 12m^3

Volume of water lost in drying = 55x0.85 - 12 = 35m^3

Assuming rate of infiltration through drying bed of 20 litre/m³ day, and 10 days to complete drying the drying bed area A is :

Rate of infiltration = 20 = $\frac{35x10^3}{Ax10}$

Sludge Drying Bed Area A = 175 m²

However; sludge layer when placed on bed should not exceed 0.3m

Thickness of sludge layer = $\frac{52}{175}$ = 0.3m.

A sludge drying bed of 10m x 175m would be adequate for a days sludge load. Ten such beds would be required for continuous operation.

Clearly evaporation although ignored in the above calculations will have a positive effect.

C/N ratio of mixed feed:

78x48 + 20x9 = (78+20) x C/N feed.

C/N feed = 40

moisture content of mixed feed:

78x0.2 + 20.06 + add.water x 1 = (78+20+add. water)0.6

Additional water = 78m³

c) **Windrow dimensions.**

Total volume of mixed feed = 226+17+78 = 321m³

Manually stacked windrow:

Provide 2 No. 3.6m wide x 1.8m high x38m long pile per day.

Mechanically stacked windrow:

Provide 1 No. 5.0m wide x 2.5m high x 39mlong pile per day.

Provide for 15 days composting prior to breaking up pile and 30 days storage for maturing. Total number of windrows required are :

Manually stacked windrow:

Provide 30 No. 3.6m wide x 1.8m high x 38m long piles.

Mechanically stacked windrow:

Provide 15 No. 5.0m wide x 2.5m high x 39m long piles.

d) **Compost Production.**

Percentage loss in weight of feed during composting	= 20%
Compostable fraction of refuse	= 70%
Moisture content of end product	= 60%
Moisture content of dried compost	= 10%
Daily weight of compost production	= [0.70(78)+20+78]x0.8
	= 122 tonnes.
Loss of moisture during drying	$= 0.6\text{x}122-0.1[\frac{0.4\text{x}\,122}{0.9}]$
	= 67 tonnes.
Final daily tonnage of dry comport	= 122-67 = 55 tonnes.

APPENDIX F - COST ESTIMATION AND FINANCIAL APPRAISAL

The quantities of various equipment required, the labour necessary to operate and maintain the service together with estimates of their costs are detailed below:

1. Estimated Capital Cost of Refuse Collection Equipment

Equipment	Number	Total Cost Rupees
Primary refuse collection vehicle- (three wheeled mopeds with containers)	75	450,000
Secondary refuse collection vehicles - (roll-off tippers with $10m^3$ containers)	5	1,500,000
Extra roll-off $10m^3$ containers	25	750,000
Sludge Tankers $6m^3$	2	600,000
	Total Rs.	3,300,000

Capital Cost of Refuse Collection equipment per $= \frac{3,300,000}{42,100}$ = Rs.78.4.

Annuetized Capital Cost(8% amortization rate = Rs.825,000 = Rs50.0/tonne compost

annuetization factor = 0.25, 5 year useful life.)

2. Estimated Capital Cost of Compost Plant.

Equipment	Number	Total cost Rupees
Front End Loader	1	580,000
Tractor, tiller and trailer	1 each	40,000
Screens (including hopper and and installation)	1	200,000
Blower fans	20	20,000
G.I. Pipes	1250m	150,000
Timers	1	300
Thermocouples	60	60,000
Conveyor belt	1	30,000

Steel Containers	5	100,000
Weighbridge and instrumentation	1	275,000
Generator	1	90,000
	Total Rs:	1,545,300

Civil Works

- covered buildings	5	5000,000
- composting pad	1	5000,000
- sludge drying bed	10	400,000
- fensing and site preparation	-	100,000
	Total Rs.	1,500,000
	Grand Total Rs.	3.045,300

Capital Cost of Refuse Disposal Facility per house = Rs. $\frac{3,045,300}{42,100}$

Annuetized Capital cost (8% amortization rate, civil works 20 years life, plant and machinery 10 years life, annuetization factors 0.101 and 0.250 respectively) = Rs. 537,825 =Rs.32. / tonne compac

3. Estimated Operating Cost Of Refuse Collection

	Annual Cost Rs.
Labour: 5 supervisors	90,000
5 Drivers	78,000
5 Driver Assistants	54,000
75 Moped Drivers/Refuse Collection	810,000
30 street sweepers	324,000
Supplies: 3% labour cost	40,680
Energy (fuel)	219,000
Maintenance: 5% capital cost	165,000
Miscellaneous: (taxes, licenses, insurance, administrative and management costs) 1% of total initial capital cost.	33,000
Total Rs.	1,813,680

(Average operating cost of refuse collection) $= \frac{\text{Rs.}1,813,680}{42100 \times 12}$ =Rs.3.6/ month

(Average operating cost of refuse collection) = (Rs.109.9)/tonne compost

4. **Estimated Operating Cost of Compost Plant**

		Annual Cost(Rs.)
Labour:	1 Process Supervisor	18,000
	1 Electrician	21,000
	1 Mechanic	21,000
	2 Drivers	31,200
	2 Watchmen	24,000
	12 Labourers	129,600
Supplies:	3% labour cost	7,344
Maintenance:	2% cost of civil works and 5% cost of plant & machinery	97,265
Energy (fuel) and Water:		290,000
Miscellaneous : (taxes, licenses, insurance administrative and management costs) 1% of total initial capital cost.		85,359
Disposal of non-compostable materials.		90,000
	Total Rs.	814,768

Average Operating Cost of Compost plant $= \frac{\text{Rs.}814,768}{42100 \times 12}$ = Rs.1.6 per month.

Average Operating Cost of Compost Plant = Rs.49.4/tonne compost

5. **Summary**

Total overall Capital cost per house = Rs. 150.7

Total overall annual operating cost. per house. = Rs. 62.4

Total annuetized capital cost per tonne compost produced	=	Rs.	82.6
Total annuetized operating cost per tonne compost produced.	=	Rs.	159.3
Total cost of producing compost	=	Rs.	241.8/tonne

APPENDIX G - SUMMARY OF DETAILED RECOMMENDATIONS

1. **Organization Management.**

Creation of a solid waste Management Department responsible for the sole function of collecting and disposing of all forms of solid wastes.

2. **Staff.**

Appointment of a Manager and supporting staff.

3. **Community Organization**

Making the community conscious of the problem of refuse disposal obtaining their support and cooperation in implementing an effective waste disposal system.

4. **Manpower**

a) Workpeople to be properly instructed in new methods and supplied with efficient tools.

b) Wages and bonus schemes be amended or introduced to incentivate the staff employed in providing the service.

5. **Storage of Waste**

a) Covered domestic containers with an effective capacity of 30 litres, made of used types to be promoted in the project area by inducing its production and diffusing its distribution.

b) Fifty demountable 0.5m containers and 5 roll-off $5m^3$ capacity containers to be made available to institutions and commercial establishments.

c) Twenty five $10m^3$ roll-of tippers to be distributed in a systematic manner over the project area to receive the waste from domestic sources.

6. **Frequency of Collection.**

Commercial clusters	-	daily
Domestic premises	-	twice per week
Institutions	-	as required

7. **Street Cleansing.**

   a) Use of 30 able bodies workpeople supplied with good tools as sweepers.

   b) Promote removal of obstructions in streets by building materials and debris.

8. **Pest Control**

   Control of vermin and the prevention of promiscuous dumping of refuse.

9. **Transport**

   a) Acquisition of sufficient and suitable vehicles and other plant.
   b) Efficient maintenance by direct labour for first line maintenance at the compost plant and , at a centralized facility for major overhauls.

   c) Weekly cleansing of vehicles and containers.

   d) Phased vehicle acquisition to a fixed life period.

10. **Equipment Purchase.**

    Local markets to provide all bins, containers and vehicles.

11. **Waste Disposal.**

    a) Cease indiscrimimate dumping.
    b) Provide official disposal and processing site.
    c) Clean up former disposal areas.
    d) Acquire suitable plant and equipment to produce compost.

12. **Resource Recovery**

    Provide facilities for manual reclamation of paper, plastics and metals.

13. Appointments

Staff

Manager	1
Zonal Supervisors	5
Process supervisor	1
Totsl:	7

Labour

Drivers(secondary collection vehicles)	5
Drivers assistants	5
Drivers (refuse processing vehicles)	2
Mechanic	1
Electrician	1
Watchmen	2
Labourers	12
Refuse Collectors(moped riders)	75
Street Sweepers	30
Total:	133

14. Equipment

Containers

30 litre	42,100
50 litre	900
$0.5m^3$	50
$5.0m^3$	5
$10.0m^3$	30

Vehicles

Three-wheeled Moped	75
Roll-off Tippers	5
Tractor Tiller, Trailer	1 each
Frond-end Loader	1

Compost Plant

Screens	1
Blower fans	20

G.I. Pipes	1250m
Timers	1
Thermocomples	60
Conveyer Belt	1
$15m^3$ steel containers	5
Weighbridge	1
Generator	1

15. **Facilities**

Office and other covered buildings	$450m^2$
Hopper	$120m^3$
Sludge Drying Beds	$1750m^2$
Mixing and composting Pad	$4500m^2$
Land	2.0ha

PLATE NO. 1

Loading operation of present day side loading refuse vehicle used in Orangi.

PLATE NO. 2

A refuse disposal site in Orangi.

PLATE NO. 3

A nighsoil dump on public access in the high density area of Tauheed Colony.

PLATE NO. 4

A used material recycle depot in Orangi.

PLATE NO. 5

Local Cabadiwala (Used Material Merchant)

PLATE NO. 6

General layout of Chinese Composting system prior to placing an insulting mud cover over the mixed feed.

PLATE NO. 7

Mud cover being placed on mixed feed in the Chinese composting system.

PLATE NO. 8

Completed Chinese composting pile showing air ducts necessary to maintain aerobic conditions within it.

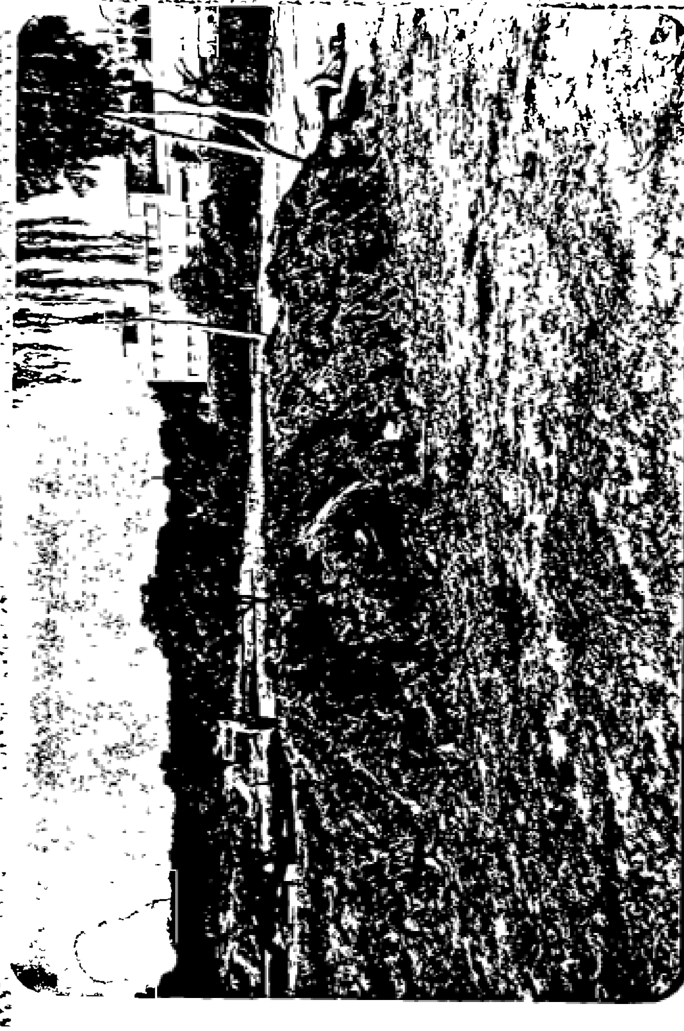



PLATE NO. 9

Two grades of sieved, dried compost prepared from Orangi refuse.

PLATE NO. 10

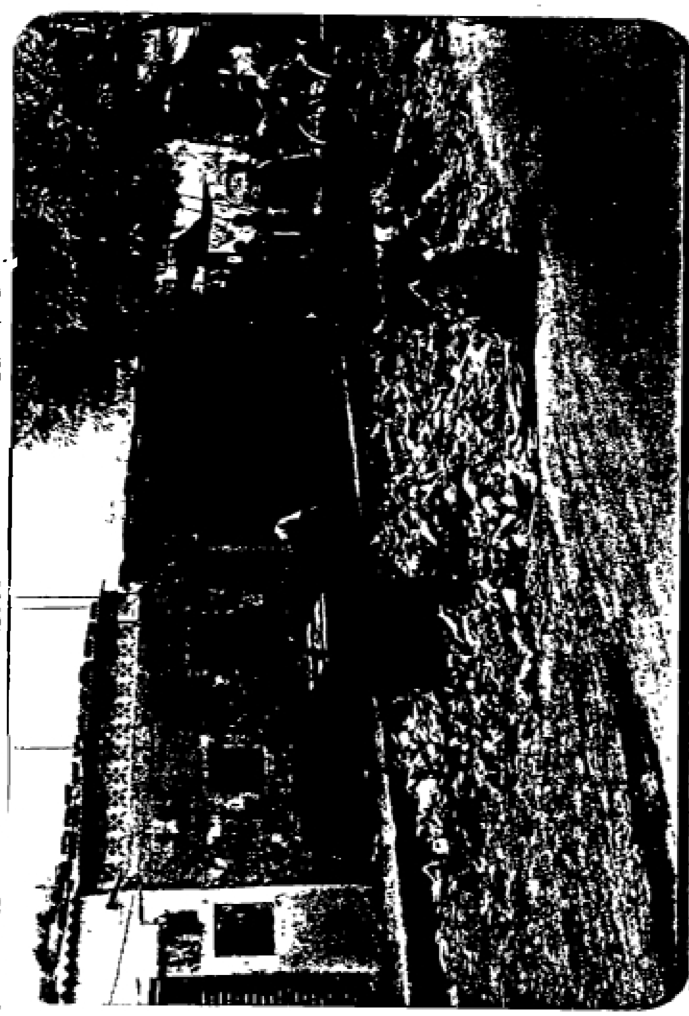
General arrangement of Windrow test pile.

PLATE NO. 11

General layout of aeration pipework for the force aerated pile system.

PLATE NO. 12

Completed force aerated pile containing mixed feed covered by a layer of dry grass for insulation.



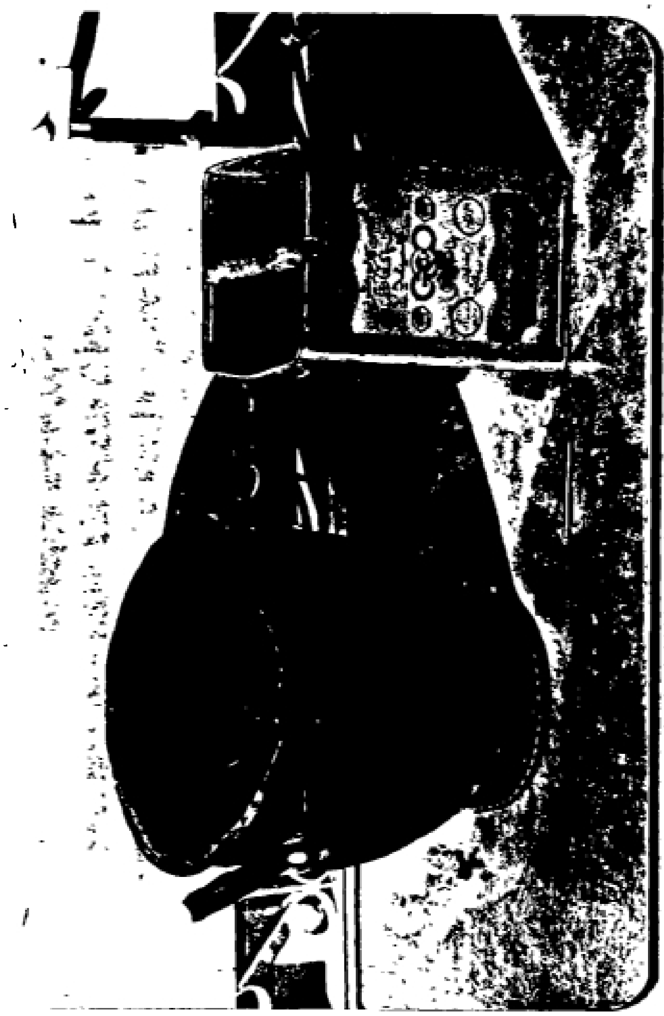


PLATE NO. 13

Three-Wheeled bicycle and container similar to the one proposed in the report as primary collection vehicles.

PLAT NO. 14

Unsuccessful attempts to use small capacity communal bins (1.5m³) in another "Katchi Abadi" in Karachi. Containers are often tipped to recover reusable materials.

PLATE NO. 15

Local Craftsman in Shershah seen manufacturing the proposed new refuse bins for domestic storage.

PLATE NO. 16

Proposed new 30 litre refuse bins made from old tyres and currently used 18 litre oil tin.