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SOLID WASTE MANAGEMENT IN A LARGE SQUATTER SETTLEMENT IN KARACHI, PAKISTAN

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FOREWORD

1. Solid waste management, as an urban service sector, receives little priority and attention in developing countries. As a result, the service is often only available to a selected few, often to those resident in the more affluent areas of cities in developing countries. Low-income urban communities are rarely provided with any waste disposal facilities or services. Yet, it is in these communities that high population densities and limited community awareness of the hazards of uncontrolled and indiscriminate disposal of refuse promote the spread of diseases and unhygienic neighbourhoods. The limited capacity of low-income communities to pay for urban services and the fact that a majority of these communities do not pay municipal taxes, has in the past, been used as the principal argument against providing any form of refuse collection service to them. There are, however, a number of factors which favour the provision of services to low-income communities. These include the fact that because a majority of these communities use all materials frugally, they only generate small quantities of highly organic refuse suitable for use as animal fodder (after separation) or for the production of organic fertilizer or compost. The potential to recover resources is often maximized in these communities, where metals, glass, paper and plastics are often retained for resale. This leads to a natural process of separation at the source that reduces the need for diverting efforts towards this end during any subsequent waste processing. Many of those in the informal sector engaged in recovering used materials for resale reside in low-income communities and rely on the proceeds of such activities for their subsistence. Where such resource recovery is maximized, it could serve as a useful income-generating activity for members of low-income communities.

2. This paper sets out some of the innovative approaches adopted in planning solid waste disposal facilities and services for Orangi - a large squatter settlement on the periphery of Karachi, Pakistan. Also included are results of investigations conducted to provide data for planning waste collection services, develop simple methods for utilizing the organic fraction of the waste to produce compost, and identify and develop suitable refuse storage containers and collection vehicles for providing a self-financing refuse collection service to the Orangi community. The economics of providing a refuse collection service are also discussed.

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* The views expressed in this document are those of the author and do not necessarily reflect the views of the United Nations Centre for Human Settlements (Habitat).

INTRODUCTION

3. The United Nations Centre for Human Settlements (Habitat) is concerned with solid-waste management because it is recognized as one of the basic services essential for promoting a healthy neighbourhood within any settlement. Activities related to waste removal and disposal can also serve to generate income for poor communities. Therefore, a comprehensive approach to human settlements development must incorporate solid-waste disposal service planning, along with the planning of land use, shelter and other infrastructure elements.

4. Habitat: United Nations Conference on Human Settlements, held in Vancouver, Canada, in 1976 recommended, among other points, that:

a) Infrastructure policy should be geared to achieving equity in the provision of services and utilities, and access to places of work and recreational areas, as well as to minimizing adverse environmental impacts;

b) Standards for shelter, infrastructure and services should be compatible with local resources, be evolutionary, realistic and sufficiently adaptable to local culture and conditions, and be established by appropriate government bodies; and

c) In the development of human settlements the quality of the environment must be preserved. Pollution should be prevented by minimizing the generation of wastes; wastes which cannot be avoided should be effectively managed and whenever possible turned into a resource. 1/

5. Subsequently, the Commission on Human Settlements recommended that the work of UNCHS (Habitat) in the field of solid-waste management should emphasize the following:

a) Promoting consideration of solid-waste disposal issues in the formulation of human settlements policies and strategies with special emphasis on meeting local needs through action designed to be consistent with local resources and capabilities;

b) Promoting appropriate refuse disposal technologies, equipment and standards affordable for low-income groups in suitably designed demonstration projects in a manner that will lead to community development with the participation of the informal sector;

c) Communicating the experience acquired to developing countries through training and the dissemination of information. 2/

6. Following this mandate, UNCHS (Habitat) has executed demonstration projects in which the provision of solid-waste disposal has been included as a component of overall settlements development activities and has published reports detailing these experiences. This paper, based on one such report, 3/ presents approaches, techniques, equipment and standards proposed for refuse disposal in Orangi, Asia's largest spontaneously developed settlement, in Karachi, Pakistan.

7. In March, 1983, the Bank of Credit and Commerce International Foundation in collaboration with UNCHS (Habitat) initiated a three year Community Development Project aimed at ameliorating the living conditions of the people of Orangi. The principal objective of the project was to promote, through co-ordinated planning, infrastructure and social programmes, the comprehensive and sustained development of Orangi as a demonstration project for replication in other squatter settlements in Karachi.

12. An overall total compostable matter of approximately 50 per cent was observed. This value compares with 10 to 20 per cent generally found in developed countries and was highest at the domestic source. The low plastic, glass and crockery content observed indicated fewer problems in disposal, especially where composting is adopted. The low-income status of the community was reflected in the very low paper and metal content recorded and, possibly, exemplifies the extent of resource recovery practised in these communities. Average values of relevant physico-chemical parameters associated with the refuse analyses are given as follows:

Moisture content	10% to 15%
Density (kg/m3)	250 to 300
Calorific value (Kcal/kg)	1500 to 1600
Total solids	85% to 90%
Volatile solids	42% to 44%
Carbon	24% to 25%
Nitrogen	0.5% to 0.7%
Carbon/Nitrogen ratio	40 to 48
pH	8.1 to 8.6

13. The average bulk density of domestic refuse appeared to undergo transformation as it proceeded from source to communal refuse bins, collection vehicles, and final disposal. The density of domestic refuse at source, as observed through sample domestic surveys, was within the range of 265 to 380 Kg/m3. However, these densities represent values corresponding to refuse collected over a period of 3 to 4 days in plastic bags given to householders who co-operated in providing domestic refuse for analysis. Natural consolidation and manual compaction by the householders were attributed to be possible causes for such high bulk densities at source. Sample checks of freshly dumped domestic refuse suggested that the naturally occurring domestic refuse density at source is of the order of 170 kg/m3. This finding suggested that some guidance should be provided to contributing householders to avoid forced compaction and that the maximum period of collection for purposes of establishing domestic densities should be limited to 48 hours.

14. The bulk density of refuse found in communal refuse storage bins averaged 315 kg/m3. However, after loading on to the side loading refuse collection vehicles, they were observed to be notably lighter, approximately of the order of 245 kg/m3. This was primarily due to the refuse handling procedures practised in Orangi. Refuse collected in communal bins is loaded on to the collection vehicles by men using forks, baskets and shovels. The high loading height of the refuse collection vehicles used in Orangi resulted in reducing the density of the refuse as it was loaded on to the vehicle. It was, therefore, clear that in order to transport a maximum pay-load, opportunity had to be taken to avoid such double handling of refuse, especially where such double handling results in reducing the bulk density of the refuse.

15. The C/N ratio of Orangi refuse was generally high, with values of the order of 47 being common. This implied that, where treatment of refuse by composting was to be considered, supplementary nitrogen inputs in the form of animal manure, nightsoil or sludge, would prove beneficial in reducing the ratio to within the optimum range of 30 to 35. Volatile solids content of samples obtained directly from domestic sources were observed to be low. This, however, was a consequence of the sampling technique adopted. The

volatile solid content of the refuse is an important parameter in establishing the carbon content and, consequently, the C/N ratio of the refuse. The sometimes advanced state of degradation of the refuse collected for analysis was responsible for these low values because some of the organic material would no doubt have been converted to a gaseous form during decomposition. The fact that some decomposition took place was indicated by the low pH values recorded for the domestic refuse samples. An average calorific value of 1400 kcal/kg was obtained by analysis and represents approximately half that usually observed in industrialized countries. Clearly, as the socio-economic status of the community rises, the calorific value may also be expected to rise as the use of paper becomes more common.

Generation of Orangi Refuse

16. The quantity of refuse produced from domestic sources in Orangi was estimated through the application of questionnaires, field observations and direct measurements at domestic sources. The results of these investigations indicated that the average daily production of domestic refuse amounted to approximately 1 litre/person/day. Direct measurements of the rate of waste generation, by weight, obtained by distributing plastic bags to households, revealed that this rate usually lies between the range 0.1 to 0.19 kg/person/day. On average, the rate of waste generation was found to be 0.17 kg/person/day. The low weight and volume recorded in this study was once again indicative of the low socio-economic status of the community and the extent of resource recovery practised in the settlement. Very few industries existed in Orangi and they were mostly confined to cottage industries producing footware, textiles, plastic ware and carpets. Since most of the scrap material was recycled in one form or the other, very little was actually discarded in the refuse. It was estimated that approximately 15 per cent of the total refuse will comprise wastes discarded from industrial and commercial establishments.

17. When planning a new waste management system, it is **essential** to take account of possible future changes in the yield, composition and density of the refuse in the years ahead. These changes will arise owing to increased socio-economic standards - a concomitant consequence of which will 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 and the construction of road pavings and kerbs become common, less sand, stones and general street debris will be present in the refuse. In order to take account of such variations, in predicting future yields of refuse the following changes in refuse weight and volume were assumed:

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

Based on the above, predicted refuse generation data were compiled and are presented in Table 2. The calorific value of the refuse could also be expected to increase with time, given the more frequent usage of paper and the reduced presence, in the refuse, of sand and debris. It was anticipated that the calorific value will increase from the present day value of 1400 kcal/kg to 1725 kcal/kg over a period of 10 years, and would continue to increase with anticipated changes in composition.

TABLE 2. PREDICTED REFUSE GENERATION DATA

Year	Population	Number of Households	Refuse 1/ Density Kg/m^3	Refuse Yield 2/ per person kg		Total Refuse Yield			
				Daily	Yearly	Working 3/ day tonnes	Working day volume m^3	Annual tonnes	Annual volume m^3
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.

Existing facilities and services

18. In order to ascertain the refuse storage and collection facilities, and the extent and efficacy of the waste disposal service available in Orangi, extensive interviews were conducted with both officials of the Karachi Municipal Corporation (KMC) responsible for the service, and with members of the thriving informal sector group engaged in waste disposal and resource recovery activities. A simple questionaire was applied to 120 dwellings to elicit information regarding various modes of domestic refuse storage and disposal adopted by the community. These investigations revealed that, at present, only 5 per cent of the refuse currently generated in Orangi was removed by the authorities. This value compares with a service level of 33 per cent for Karachi, in general 6/. A majority of the householders stored their refuse in used 18 litre cooking oil containers. On average, each person was observed to produce 1 litre of refuse each day. Over half the householders interviewed dumped their refuse once daily, but approximately an eighth of those interviewed dumped their refuse only once a week. Refuse was commonly dumped in the street in front of the house, or where non-perennial water courses existed nearby, dumped along its banks. Only 2 per cent of those interviewed dumped their refuse into communal storage facilities provided by the authorities. The limited use of these facilities was indicative of the extremely limited number of communal storage bins made available in the area. Only an estimated 8 bins, with an overall storage capacity of 6.4 m^3, were available in the area to serve a population of 320,000 people. Under half the population practised some form of resource recovery, of which the sale of "roti" (unleavened bread), used bottles and glassware, were the most popular items for resale. Metals, paper and plastics, were other items retained by the householders for resale. The sample domestic survey revealed that, except for a few premises, storage at individual dwellings and other properties was unsatisfactory - uncovered and non-standard receptacles were in general use - and much waste was disposed of directly into the streets and to vacant land. Uncontrolled burning of accumulated refuse was ubiquitous in the project area.

19. The refuse collection and disposal service in Orangi was grossly inadequate. Besides the very limited communal storage facilities provided in the project area, only a single $6m^3$ side loading refuse vehicle was deployed to collect the refuse from the project area and adjoining settlements in Orangi. One driver and 4 refuse collectors were employed to conduct all operations relating to refuse collection. A few street sweepers were employed in the area to sweep the few surfaced streets and adjoining footpaths. The sweepings were discharged to the communal refuse bins. The process of loading the accumulated refuse on to the collection vehicle was indeed labour-intensive and time consuming. More time was spent in loading the vehicle, using forks, baskets and shovels, than in coumutting to and from the disposal site. The side loading vehicle used was clearly unsuitable for loading lighter refuse because of its high load height. It was originally designed for heavy materials. Although designed to carry a payload of 5 tonnes, it was rarely observed to carry loads in excess of 2 tonnes. When loaded above the sideboard, refuse was observed to blow about.

20. The collected refuse was officially intended to be transported to a landfill site in North Karachi, some 10 kms away from the settlement. Owing to the inadequate access to the site - warranting passage through built-up residential and commercial areas - and the little control exercised in the dumping of wastes, the collected refuse was invariably dumped at unofficial sites within Orangi and at its periphery, and presented severe public health hazards.

21. Two types of informal sector activities related to the management of solid waste were observed in Orangi. The first comprised of private individuals, who, by means of animal-drawn carts, transport refuse from markets and commercial establishments to dump sites selected at their discretion, invariably chosen with the intent to reduce haulage. This had further increased health hazards in the area. A nominal fee was charged for this service. The second type of informal sector activity, and easily the more prosperous, was conducted by "Kabadiwalas" - used materials merchants. Five used-material depots were present in Orangi that were fed by an estimated 50 door-to-door sales persons who purchased used articles directly from residents. The depots were also fed by an army of individuals who pick-up and transport, in sacks, any discarded materials of value they come across. They were observed to scavenge refuse bins and dumps for this purpose. Unit prices of a variety of recycled materials is given in Table 3. Entire families, including children, engaged in scavenging used materials from the official dump site in North Karachi, were reported to earn as much as rupees 300 (approximately US$19) each day. The only fraction of refuse produced, which was not in any way recycled, comprised of organic matter up to two-thirds the total weight of refuse.

TABLE 3. 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

Compostability of Orangi Refuse

22. Over two-thirds, by weight, of the composition of Orangi refuse was observed to be compostable and represented precisely that fraction of the refuse which was not being utilized in any way. Recognizing the potential that refuse composting could play in treating the waste generated in Orangi, and the possibility of creating income generating activities within the communities, the project investigated simple techniques of composting which could be imparted to those engaged in the informal refuse disposal and reuse sector. The compost, as an end product, was thought to serve as a useful soil conditioner for local application, but also had a considerable foreign market namely in the Middle Eastern Gulf countries. The advantages that aerobic composting processes possessed over anaerobic processes in producing an odour and pathogen free humus in a short period of time, led to the confinement of the investigation to aerobic processes only. Three techniques of producing compost utilizing differing degrees of mechanization for application to differing scales of production, were investigated. These included:

a) Chinese covered pile system;
b) Windrow system;
c) Force aerated pile system.

a) Chinese covered pile system

23. In this method, bamboo poles were placed 1.00m apart in a criss-cross pattern on a bedding of 0.15m of dry grass and vertical poles attached at the crossing points. Refuse was, then, mixed with 15 per cent poultry wastes and water added to the mixture prior to placing it in a heap approximately 1.20m high. The poultry wastes and the water were added in order to bring the principal parameters which affect composting to within the acceptable range of values shown in Table 4. Large stones and cloth were removed from the refuse prior to mixing. No shredding or grinding was done before preparing the compost process 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. Straw was added to the clay to reduce shrinkage.

TABLE 4. DESIRED VALUES OF AEROBIC 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%
Airflow	0.5-1.8m^3 air/day/kg volatile solids
Temperature	55-65°C
pH	7.5-8.5

Sources: 7/, 8/, 9/

24. After a day, when the soil covering had dried, the poles were removed to leave air ducts. Thermocouples placed inside the covered pile were used to monitor the process, because temperature, perhaps, more than any other parameter, is a good process performance indicator for aerobic composting. The temperature changes observed during the composting process is presented in Figure 1. Temperatures as high as 66°C were attained in a few days and thus maintained for up to 10 days. Maintaining these high temperatures for considerable durations would ensure the destruction of all pathogenic organisms.

25. The physico-chemical analyses of the raw refuse used, the feed prepared, and the resulting compost are presented in Table 5. Because 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 and potassium contents of 1.0 and 1.1, observed in the end product, indicated that the material was suitable for use as a soil conditioner.

TABLE 5. 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
Potassium	-	-	-	1.1

26. A 20 per cent weight loss between feed and final compost was measured. The percentages, by day weight, of material in the final compost, as observed through analyses, is shown in Table 6. An overall compostable fraction of approximately 71 per cent 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 content and free from disease causing organisms. Bacterial analyses were conducted to confirm the latter (see Table 7).

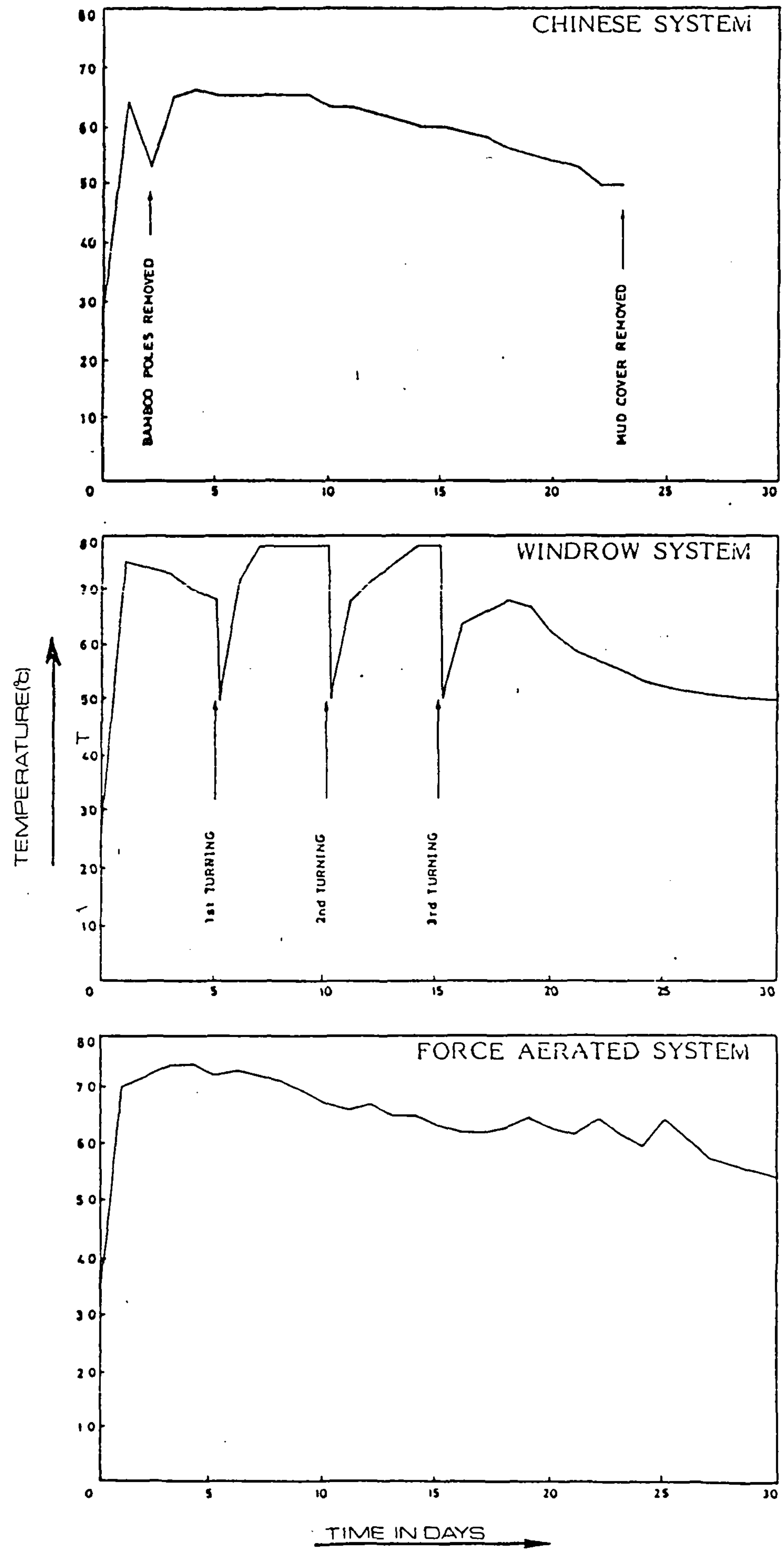


FIGURE 1 - THERMOGENESIS OF TESTED SOLID WASTE COMPOSTING SYSTEMS

TABLE 6. COMPOSITION BY PERCENTAGE DRY WEIGHT OF FEED MIX AFTER COMPOSTING

NATURE OF MATERIAL	PERCENTAGE		
	CHINESE SYSTEM	WINDROW SYSTEM	FORCE AERATED SYSTEM
Compost	70.9%	68.7%	70.9%
Bulky Orangi Material for recycle	4.3%	2.5%	3.5%
Stones, glass and crockery	8.8%	18.2%	11.0%
Wood	1.8%	2.0%	2.1%
Bones	0.8%	0.5%	0.4%
Cloth, leather, plastics and metals	13.4%	6.0%	12.1%

TABLE 7. RESULTS OF BACTERIAL ANALYSES OF REFUSE AND COMPOST

	CHINESE SYSTEM		WINDROW SYSTEM		FORCE AERATED SYSTEM	
ORGANISM	NUMBER PER GRAMME OF REFUSE	NUMBER PER GRAMME OF COMPOST	NUMBER PER GRAMME OF REFUSE	NUMBER PER GRAMME OF COMPOST	NUMBER PER GRAMME OF REFUSE	NUMBER PER GRAMME OF COMPOST
Total Bacterial Count	$8.3x10^7$	$6.3x10^6$	$9.3x10^6$	$4.5x10^5$	$8.3x10^6$	$5.5x10^6$
Fungi	$5.0x10^6$	$3.3x10^5$	$9.0x10^5$	$8.0x10^6$	$8.6x10^5$	$7.4x10^5$
Actinomycetes	$1.6x10^6$	$1.6x10^6$	$4.5x10^5$	$4.3x10^3$	$4.6x10^5$	$4.2x10^5$
Enteric Bacteria	$5.3x10^3$	0	$6.8x10^3$	0	$6.8x10^3$	0

b) Windrow system

27. Windrow is an aerobic composting process, applied extensively in India, requiring very little mechanical equipment. It has been adopted for processing refuse from cities with large populations. As may be inferred from the name "windrow" or open composting system they are characterized by 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 per cent 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 prior to mixing. The windrow was turned on the 5th, 10th and 15th day following mixing.

28. Temperature changes observed during the composting process are presented in Figure 1. Very high temperatures, as much as 78°C were recorded. Since even the most resistant pathogenic organisms present in the refuse are destroyed after a few minutes at temperatures in excess of 60°C, in composting systems, temperatures above 65°C are counter productive and lead to large nitrogen losses and a slowing down of the process, as micro-organisms, causing the breakdown of the organic material, begin to die.

29. Physico-chemical analysis of the raw refuse used, the feed prepared, and the resulting compost, is presented in Table 8. The results of these analyses would indicate that the windrow process took more time to produce a stable compost and was perhaps, a consequence of the high temperatures attained. More frequent turning of the pile may, perhaps, be used as a means of controlling the temperature to the optimum range of 60-65°C. A 20.4 per cent weight loss was observed during the composting process and was a result principally of the liberation of carbon dioxide, but also of some other gases. The percentages by dry weight of material in the final compost are shown in Table 8. An overall compostable fraction of approximately 69 per cent was observed and, once again, confirmed the fact that over two-thirds of Orangi refuse was compostable. Bacterial analyses indicated that the final end product was free of enteric bacteria, as shown in Table 7.

TABLE 8. 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

c) Force aerated pile system

30. This method of composting is similar to that of the windrow system, except that the need for turning the refuse mix is obviated by placing a pipe grid below the feed and above a 15 cm layer of dry grass. A 6.6m x 1.5m rectangular pipe grid made of 75 mm diameter G.I. pipes was used in the control experiments. A series of orifices varying in diameter from 2mm to 6mm from the end near the pump to the far end, respectively, were placed along the pipe grid. Three rows of alternating series of holes were made in the pipework in a manner similar to that of subsurface drains. The pipe 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 per cent poultry wastes and water as required. A layer of dry grass was placed over the feed to provide insulation and protect against water loss.

31. The temperature changes observed during the composting process are presented in Figure 1. Temperatures were observed to drop to around 50 to 55°C when the blower was operated, but, on average, temperatures were observed to be within the optimum range indicated on Table 4. The results of physico-chemical analyses of the raw refuse used, the feed prepared, and the resulting compost, are presented in Table 9. These results indicate that organic degradation proceeded well in this process and that a stable compost was produced in 3 weeks. High-percentage nitrogen and potassium contents of 1.4 and 1.0, respectively, were observed in the final humus. A 21.5 per cent dry weight loss was observed during the composting process. As may be seen from Table 6, an overall compostable fraction of 71 per cent was obtained. Enteric bacterial counts undertaken of the final humus produced revealed no viable organisms.

TABLE 9. PHYSICO-CHEMICAL ANALYSIS OF REFUSE, FEED AND HUMUS-FORCE AERATED SYSTEM

PARAMETER	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	18.3	18.6
Nitrogen N %	0.57	0.84	1.4
C/N	42.0	22.3	13.3
Potassium	-	-	1.0

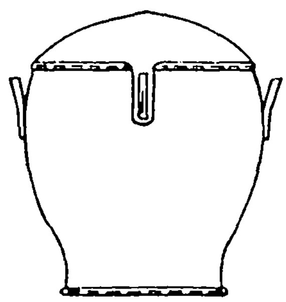
32. The composting trials conducted during the study led to conclude that the Orangi refuse was suited for producing considerable quantities of good quality compost. The three techniques investigated were simple enough to be adapted for application in Orangi. The Chinese composting method appeared to offer the best control conditions of the composting process and is suitable for adoption by the informal sector. Where very large quantities of compost are required to be produced at a central plant on a continuous basis, the windrow or force aerated pile methods may be more appropriate. Some extra care was considered necessary with regard to the windrow system to maintain relevant process control parameters within optimum limits. The fact that all composting processes tested yielded pathogen free humus indicates that any refuse contaminated with human excreta (usually from houses without adequate sanitation facilities) could be made innocuous through composting. The low percentages of glass and ceramic ware found in Orangi refuse make it ideal for field application. Glass and ceramic ware make the final humus less attractive for agricultural reuse. Although no initial shredding was necessary, such pretreatment could no doubt speed-up the composting process. Sieving after composting was, however, necessary to produce a homogeneous humus material.

Proposed Refuse Collection Service

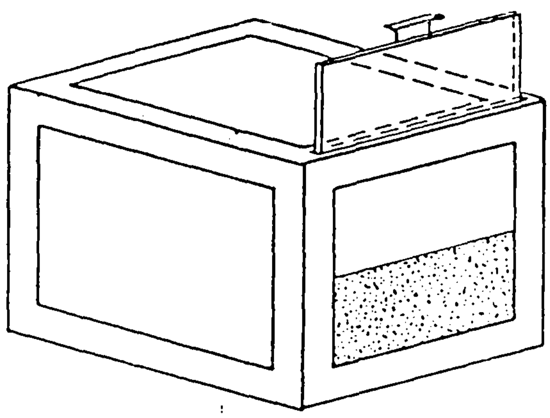
33. The purpose of a refuse collection service is to provide an effective system for the removal of all solid household and commercial waste from the project area, either from the individual premises or from central collection points. Removal of street litter and waste is also an essential part of the service.

34. Of prime importance in the collection of refuse from Orangi was the need to change the present-day practice of utilizing used 18 litre oil tins for domestic refuse storage. These containers were found to be susceptible to damage owing to rough handling, corrode rapidly and provide no protection against the breeding of flies. The containers, being made of metal, could not be readily washed out without promoting corrosion. An alternate domestic container fabricated from used tyres was developed by the project and produced locally using indigenous artisans. Although the size of the container could vary, a 30 litre container was recommended for purposes of standardizing the containers. The container, being made of rubber and possessing a lid, facilitates washing and prevents the breeding of flies. The cost of the domestic refuse container developed by the project was US$1.50. Similar containers were envisaged to be provided for small commercial and institutional establishments. Larger cube shaped containers made from either GI sheets or wood which could be loaded directly on to the back of a 3 wheel-moped were envisaged for the large commercial and institutional establishments. The capacity of such a container was envisaged to be approximately $0.5m^3$.

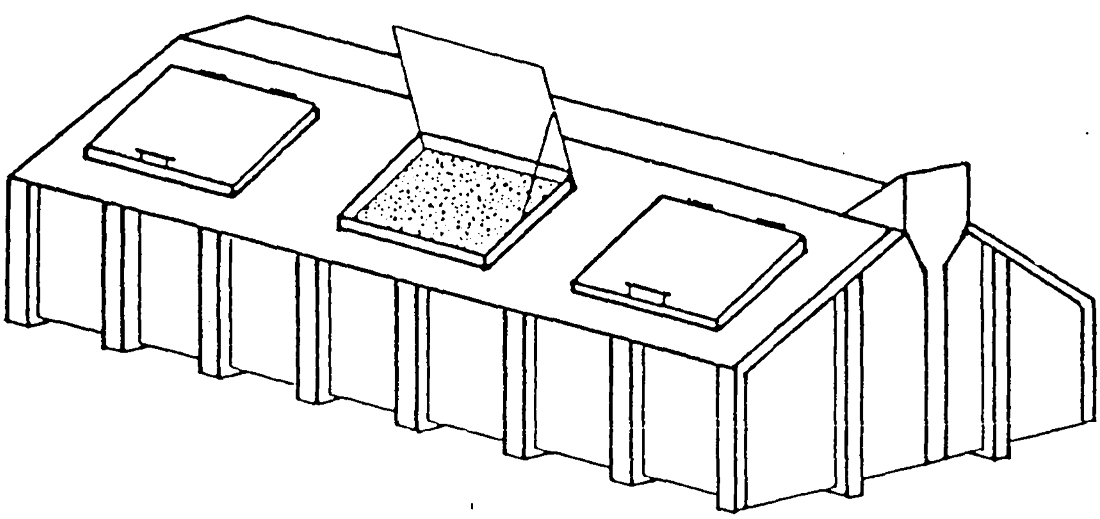
35. Ten cubic metre roll-on, roll-off containers, distributed throughout suitably accessible locations within Orangi, were recommended for use as secondary refuse storage containers. These large secondary, or communal, storage containers were planned to be fed with the refuse collected from domestic sources and small commercial and institutional premises by means of a primary refuse collection vehicle, namely a moped. Attempts to utilize small $1.2m^3$ capacity containers as communal refuse storage containers proved unsuccessful in the various parts of Karachi where they were tried because they were often turned over by scavangers. The design of the $10m^3$ containers proposed was such as to dissuade such scavenging. Illustrations of the primary and secondary refuse storage containers proposed for Orangi are shown in Figure 2.



30 LITRE DOMESTIC STORAGE BIN



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

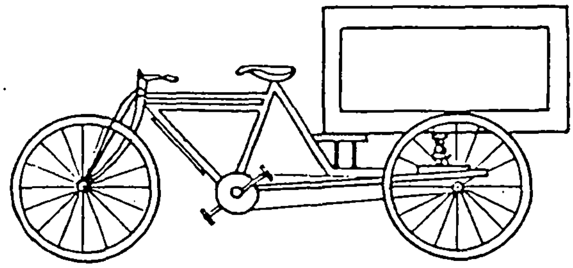


5 - 10m³ ROLL-OFF CONTIANERS

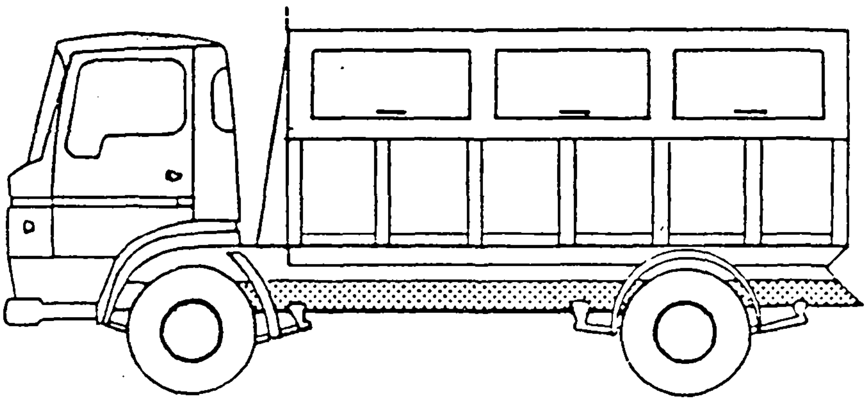
FIGURE 2 - PROPOSED REFUSE STORAGE CONTAINERS

36. It was proposed that the project area be judiciously divided into 75 sectors, each served by one collector who would be entrusted the responsibility for collecting, on a twice-weekly basis, the refuse placed on the kerbside by the householders and shop-keepers. Each collector was to be provided with a three-wheeled moped with a single container of 500 litre capacity. Three wheeled cycles are common in Karachi and are generally used to transport vegetables and fruit. It was proposed to fit a motor to the cycle to facilitate transit. The collector would discharge the waste accumulated in the container into the nearest 10m3 communal storage container. Twenty-five such containers were initially required with 3 adjacent collector areas feeding a single communal storage container. Five roll-off communal container tipper vehicles were required to remove the 25 communal containers on a rotary basis for treatment by composting. The main advantage of the roll-off tipper vehicles is that they avoid the need for double handling of refuse, as was practised with the side loading refuse vehicle, and hence ensure the transport of a maximum pay load. Investigations revealed that double handling, i.e., the manual loading of refuse collected in a communal storage container on to a collection vehicle, results in reducing the density of the refuse. Clearly, the highest pay-loads are obtained when the communal containers are themselves loaded on to the collection vehicle and transported directly to the disposal site. This is conveniently achieved by means of demountable containers which may be rolled-on and rolled-off the chassis of the collection vehicle with the aid of hydraulically operated arms. The modus operandi of the roll-off collection vehicle ensures considerable savings in the time spent in loading the refuse on to the vehicle. Illustrations of the primary and secondary refuse collection vehicles recommended under the study are presented in Figure 3. The density of the refuse being naturally high eliminated the need for compaction vehicles. Present day access roads would also have acted as a constraint to their adoption.

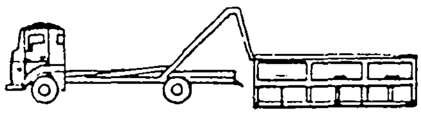
37. Two alternative approaches for the disposal of the refuse collected were considered. Both alternatives were based on the recovery of reusable materials and the production of compost. The first method entailed the organization of existing informal sector personnel to collect or recover reusable materials and produce compost from well defined areas within Orangi. It was envisaged that only primary collection vehicles would be necessary in such a case. In order to ensure a comprehensive service to all members of the community, however, it was necessary to consider a unified system servicing the whole of Orangi. The entrusting of the entire operation to a private enterprise for exploitation on a commercial basis, however, proved feasible. For this reason, it was necessary to consider the use of secondary refuse collection vehicles and a centralized refuse composting plant. The force aerated composting system was recommended with a daily production capacity of 55 tonnes. Besides space for stocking compost piles, provision was also made for manual picking and final screening of the end product after composting. One tractor and tiller and a front end loader were recommended for preparing the compost mix and for placing the mix in a pile. Civil engineering works proposed at the site included an office, laboratory, workshop, store and weighbridge, and instrumentation house. Manpower requirements for refuse collection and composting plants, respectively, are given below:



PRIMARY REFUSE COLLECTION VEHICLE



SECONDARY REFUSE COLLECTION VEHICLE

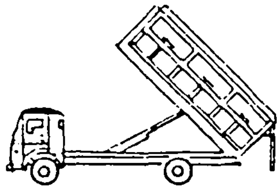


Ready to lift container

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 3 - PROPOSED REFUSE COLLECTION VEHICLES

Collection:	1 manager	Composting:	2 drivers
	5 Zonal supervisors		12 labourers
	75 Moped drivers/refuse collectors		2 watchmen
	5 collection vehicle drivers		1 mechanic
	5 collection vehicle assistants		1 electrician
	30 street sweepers		1 process supervisor

Service cost and affordability

38. The capital cost of providing a comprehensive unified system of refuse collection and disposal was determined in order to establish the financial feasibility of introducing the service. Cost estimates were prepared on local prices for basic materials, labour and plant, assuming full implementation including the provision of all containers, three-wheeled mopeds and roll-off tippers. All cost estimates are exclusive of engineering fees and land costs. The overall capital and operating costs (1983 prices) of the proposed refuse collection and processing system were as follows:

Total capital cost of refuse : collection equipment	= Rs. 3,300,000
Total capital cost of compost : plant and equipment	= 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

39. Assuming a rate of amortization of 8 per cent and the life of plant and machinery, and civil works of 5 and 20 years, the cost of producing a tonne of compost may be established as follows:

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

40. Although no detailed market studies were conducted by the project to establish the marketable value of compost, it was established that export markets in the Middle Eastern countries could fetch returns as high as Rs. 750 per tonne of compost. Large quantities of animal manure exported to these markets fetched similar prices. Although the cost of freight has not been added to the overall cost of producing compost established above, it is evident that the entire collection and disposal

service could be provided to the community at no cost. Even where no cost recovery through the sale of compost was possible, the service was affordable to the community in general given their present day levels of income.

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
Average annual household income	=	Rs. 10,800

41. Besides composting, additional benefits may also be derived from the recycling of other materials present in the refuse. The 4 per cent paper, 1.5 per cent plastics and 0.35 per cent metals, are the more important of the recyclable materials. Based on the current resale value of these materials presented in Table 3, it was estimated that a net annual income of over Rs. 3.1 million or an equivalent annual per household income of approximately Rs 75 was possible. Even using labour intensive methods, resource recovery has a great potential to off-set some of the cost of providing a refuse disposal service.

Conclusions

42. The investigations conducted by the community development project into suitable means of disposing of solid wastes from the low-income squatter settlement of Orangi, led the project to conclude the following:

(a) It was possible to offer a comprehensive refuse collection and disposal service within the project area at an affordable cost to the beneficiaries;

(b) The Orangi refuse was suited for composting and offered potential to utilize precisely that proportion of the refuse which was not being reused in any way;

(c) The production of compost and the recovery of other reusable materials as an integral part of collecting and disposing of refuse has the potential to provide a self-financing refuse disposal service in Orangi;

(d) The production of locally manufactured domestic containers and the involvement of personnel from the community in activities related to the recovery of resources, can create useful income generating activities for low-income communities.

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