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A B S T R A C T

The present paper discusses various aspects of solid waste service in Calcutta City and in the municipalities in the Calcutta Metropolitan Area. The issues considered include mechanisation and improvement of the solid waste service, economising costs of solid waste management, alternative methods of solid waste disposal and recycling. In the conclusion the paper suggests some policy measures.

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1. INTRODUCTION

According to some recent estimates, Calcutta city generates 2000 tons of solid waste every day, with an estimated volume of 448 thousand cubic feet[1]. To get rid of this waste the city authority make an annual revenue expenditure of Rs. 218.5 millions, which accounts for about 20% of the total revenue expenditure[2]; the cost per ton of solid waste removed amounts to about Rs. 229. Besides, the municipalities in greater Calcutta account for another 827 tons of waste per day, which involve an annual expenditure of Rs. 47 millions[3]. Despite this heavy expenditure, solid waste management in the city, as well as in the suburban municipalities, is far from satisfactory, while the cost of this service is going up all the time because of inflation and wage increase. The problem is, therefore, to keep Calcutta and its suburbs clean at the minimum possible cost.

The cost of solid waste service is largely influenced by city-specific factors, e.g., the sources of solid waste, the generation pattern, the composition and characteristics of solid waste, and the related socio-economic parameters. In section II we will discuss these in case of the Calcutta city, while in section III the existing system of solid waste service in Calcutta city will be reviewed. Section IV examines issues relating to efficiency and scope for improvement of services and technological issues. In Section V we give an account of the problem of solid waste management in 36 municipalities[4]. In section VI major policy issues in connection with the solid waste service will be discussed.

II. FEATURES OF SOLID WASTE IN CALCUTTA

The municipal waste is classified by source into the following types : household garbage and rubbis, commercial refuse, institutional refuse, street sweepings, construction and demolition debris, sanitation residue and industrial wastes. The specific features of each of these types are discussed below with special reference to the city of Calcutta.

Household garbage and rubbish, also referred to as residential or domestic refuse, consist of wastes generated through household activities, namely food preparation, fuel burning, gardening, etc. Used materials and old cloths are also included. In Calcutta, as in the cities in the other developing countries, the major component of the domestic waste is the kitchen waste, i.e., food preparation and fuel burning wastes. Other types of domestic waste, such as paper, glass, metal and plastic etc., account for a small proportion because scavangers collect such items directly from the households against small payments. A significant portion of the domestic waste is thrown indiscriminately on the streets by both the bustee dwellers, who may not have space for in-house storing of refuse[5], as also the relatively well off. While this is partly owing to the absence of a developed system of house to house collection, lack of civic consciousness is also an important factor.

Commercial refuse consists of waste from retail and wholesale markets, warehouses, stores, hotels and restaurants. In Calcutta there are 152 markets[6], of which special mention may be made of Kolay market, a major wholesale vegetable market, and 'fall-patty', a wholesale market for

fruits in Burrabazar, both of which generate huge amounts of refuse daily[7]. Apart from the organised commercial activities, there are various unorganised commercial activities, like street vending of vegetables and green coconut, wholesale trading in seasonal fruits (like mango and liches) on pavements and tea and other food stalls on the street. While organised markets contribute the major portion of the waste in this category, wastes from the informal sector, which include used earthen tea pots, green coconut shells, shal leaves, extracted stem of sugar-canes and ashes, are most visible, such wastes are generated throughout the day and evening and give the city an unclean look.

Institutional refuse consists of waste generated at schools, hospitals, government offices and religious buildings. Though hospital wastes should be treated separately for sanitary reasons, in Calcutta it is collected and dumped with other municipal garbage.

Though refuse collected from street sweeping is supposed to include dirt and litter only, in Calcutta, where the primary method of refuse disposal from household and small commercial establishments is 'placement' of waste in individual and communal heaps along the road side, it contains an appreciable amount of household refuse. It includes silt from drain cleanings, human faceal matter and animal manure also. Many pavement and bustee dwellers, for lack of better sanitation services[8], directly release faceal matter to open drains and road, while dung comes from the sizeable number of freely roaming cattle and dogs.

Though the Corporation collects construction and demolition debris on payment of charges[9], the bulk of such

wastes are purchased by the private traders, who sale the material for land-filling. However, waste generated while carrying out minor repair of buildings are dumped into the street, as also debris and soils from the repair of underground public utilities.

In many areas of the city proper sewerage is not available for disposing of human excreta and sullage; in 1986, the Calcutta Corporation had to attend to about 8000 privies[10], as also silt extracted from the underground and open drains.

Industrial wastes come from industries as well as utilities like water-works and electricity generating stations. Industrial wastes consist primarily of packaging materials, food wastes, spoiled metal, plastic, textile etc. While large scale industries are usually either required to arrange for a private hauler or to pay a fee to the municipality for special service, small scale industrial enterprises generally discharge their solid waste into the collective milieu of the municipal refuse.

In Calcutta, solid wastes from different sources, namely, domestic, commercial and institutional as well as from street sweeping are not really separable. In view of the tropical hot climate, the organic component of household and market refuse putrefies quickly and therefore wastes from these sources require frequent removal, daily or on alternate days. Though the removal of construction and demolition debris and industrial waste is not the task of the Corporation, a portion of such refuse is usually mixed with the regular municipal refuse and cleared by the municipal authority.

Quantity of Solid Waste

There is no firm estimate of solid waste generated in the city in a day[11]. Estimates of the quantum of solid waste generated in the municipality should include not only garbage from households and various commercial places, but also items like sludge from drains, street sweepings etc. However, the estimates reported do not usually include sludge or sanitation residue. In this paper we will treat the terms 'refuse' and 'solid waste' interchangeably unless mentioned otherwise.

Table 1 shows various estimates of refuse produced per day in Calcutta since the early 1960s. For none of these estimates the method of estimation has been explicitly spelt out; nor the area covered or the types of refuse included. The usual method of estimating the quantity of garbage is to multiply the number of truck trips required for garbage removal by the capacity of the truck used. This method is likely to produce overestimates in view of the absence of no weigh bridges at the disposal sites and the reported frequent underloading of the trucks[12]. Besides, the non-uniform density of refuse from different parts of the city would imply that variations in the volumetric capacities of the trucks would not correspond to their weights. For Calcutta city (excluding the recently added areas of Jadavpore, South Suburban and Garden Reach) no trend can be observed from the available estimates. However, barring a few exceptions, e.g., estimate by the Talukdar Committee in 1962, by Vincenzin in 1963 and by Samadder in 1975, it is observed that solid waste generation in the city area has increased over time : from about 1300 tons per day in the early sixties to about 2000 tons in the late eighties.

Per capita generation has increased from around 450 gm. per capita per day in 1963 to about 600 gm. per capita per day in 1989[13]. These estimates possibly do not include the silt and sludge excavated from underground drains; in 1975 about 400 tons of silt were removed daily[14]. There is no source-wise estimate of refuse for Calcutta. For the cities of developing countries the sourcewise generation rates are taken to be as follows[15] :

Type of refuse	Amount (in kg. per capita per day)
Residential	0.3 to 0.6
Commercial	0.1 to 0.2
Street sweeping	0.05 to 0.2
Institutional	0.05 to 0.2

Assuming that the lower boundary values held for Calcutta in the early eighties, the commercial refuse in the city were around 332 tonnes daily and institutional refuse around 145 tonnes daily[16].

Apart from the total quantity of refuse generated and source-wise break up, information about refuse characteristics - namely, density, composition, moisture content and chemical characteristics and size distribution - are essential for evolving a cost efficient solid waste service; for Calcutta available information on these are far from adequate.

Density : Refuse density information is crucial;when coupled with waste generation rate expressed by weight, it allows the pay load capacity of the collection equipment to be estimated. When this payload capacity is divided by the number of trips feasible for various regions of the city, it is possible to estimate the number of vehicles required to be on the collection routes each day.

Density of refuse varies from the generation point to the disposal site. In Calcutta density of uncompacted refuse at the generation point is about 463 kg/cm ; the refuse density increase by about 11% as the refuse gets compacted due to self-weight and vibration during movement. At the disposal site, the density value is 517 kg/cm in collection vehicle[17]. Further, after disposal by open dumping, where no-compaction is performed, and resting within the dump for six months, the refuse naturally consolidates to a density of 1100 kg/cu.m.[18].

Composition and characteristics : Refuse composition depends on a number of factors such as food habits, cultural traditions, socio-economic and climatic conditions. Composition and characteristics of refuse vary within the same city according to area and season.

In the early 1970s, on the basis of 308 samples from 154 dumping points, National Environment Engineering Research Institute (NEERI)[19] of Kanpur carried out an analysis of physical and chemical characteristics of the city refuse. The average values of physical and chemical characteristics, as percentage of weight, were obtained for the city as a whole and also for the four conservancy districts (Table 2). However, no marked difference was observed between districts, possibly because of mixed land-use pattern. Moreover, it reported refuse characteristics for residential, commercial, market and industrial areas separately. Further, residential areas were classified into high, middle and low income areas and slums (Tables 3 and 4). It was observed that, in the high income areas, the proportion of paper, plastic and glass is relatively high. This was also true of the

proportion of organic matter consisting of leaves and garbages. In the slum areas the proportion of hay and straw was relatively high, while in the commercial and market areas the proportion of the organic matter was higher. Compared to other areas, the moisture content was more for refuse coming from the industrial areas and slums.

In Calcutta the refuse density is higher compared to that for the cities of the industrialised countries, because of the low percentage of non-putricibles such as paper (3%), polythene and plastics (0.65%) which are used for packaging of consumer goods (Tables 5 and 6).

In Calcutta moisture content of refuse is high (41%) compared to that in Madras (39%) or in Bangalore (33%) but low compared to Bombay's (51%). It is higher than that for the industrialised countries (Table 7), due to the presence of a higher proportion of fresh and unprocessed vegetable wastes. Besides, the moisture content is somewhat dependent on climatic condition, especially in places where refuse is stored on open ground while awaiting collection, as in Calcutta's case. However, no information on the moisture content of various components of the total waste-mix is available. As moisture content of each component of refuse differs greatly, compositional percentage on wet weight basis, as reported above, would be quite different from those on a dry weight basis.

The proportion of organic (or compostable) matter is not high in case of Calcutta (42%). Unpaved roads, frequent digging of the surfaced roads and seasonal conditions tend to increase the ash and soil content; ash and earth accounts for as much as 34% and burnt earthen ware another

7%. As a result, the calorific value is a low 1504 kcal/kg, compared to USA's 3330 kcal/kg. Calcutta's figures are, however, better than those for the other Indian metropolis (Table 7).

III. SOLID WASTE MANAGEMENT IN CALCUTTA

Solid waste service consists of three broad categories of operations, namely collection, transportation and disposal[20]. Efficiency of the service requires adequate coordination among these three operations. Moreover, collection operation is decentralised over space and, therefore, requires a close supervision. In this section, after a brief historical account of the evolution of solid waste management, we discuss the administrative set-up of the Corporation for solid waste management, followed by a discourse on each of these operations and their corresponding costs.

An important land-mark in the solid waste management in the city was the acquisition of the 'Dhapa Square Mile' in 1866 for disposal of the city refuse. Before that solid waste was used to be disposed of in the low-lying areas within the city itself, including the Maratha ditch[21], a waterway which then encircled the city, but which was latter covered up. Even in early nineteen sixties, there was no separate department for solid waste operation in Calcutta. While the actual cleaning work was carried out by the Engineering Department with the help of engineers responsible for four service districts, the vehicles for transportation were under the control of the Motor Vehicles Department. Usually, the solid waste was carried by the municipal vehicles to the refuse loading platform of the municipal railway at Chingrihata, wherefrom it was taken in the wagons to the dumping site at Dhapa by the Municipal Railway -

another department. At Dhapa the unloading of the wagons and disposal of the refuse were done by the workers under the control of the private contractors[22]. Transportation of refuse was not fully mechanised, for instance even in the 1960s, in Tollygunge area, refuse was carried by the bullock carts.

The multiplicity of agencies resulted in a lack of coordination and mismanagement. One of the major recommendations of the Corporation of Calcutta Enquiry Committee of 1962, for improving solid waste management, was to bring the operations related to the service under a single administrative unit[23].

The use of the private contractor at the Dhapa end ceased in 1970[24], while transportation of refuse by the municipal railway was discontinued after 1976[25]. Meanwhile, in 1975, the entire operation of solid waste management was brought under a single directorate, namely the conservancy directorate, consisting of the Motor Vehicles Department in charge of the vehicles, and the public health engineering department in charge of the collection operation. In 1980, in place of the four service districts (along with some added areas) the city solid waste service as well as other civic services were organised borough-wise.

The Administrative set-up

At the borough level, under the supervision of the borough committee, a conservancy supervisor is responsible for a number of wards. For each ward, there is a conservancy overseer who monitors garbage removal in about ten conservancy blocks which comprise the ward, while, for each block, a block sarker supervises the work of ten conservancy labourers. On an average, one conservancy block covers a population of 4000[26].

Collection

In Calcutta, refuse is collected in most areas from the roadside heaps, community bins and street sweepings; only in some areas there exist the system of house-to-house collection[27]. Refuse collected is carried to large roadside vats wherefrom transportation vehicles are loaded. The collection of refuse in vats is known as 'primary collection'.

Primary collection (including road sweeping) is done manually by a crew consisting of three conservancy mazdoors with one handcart of 9 cft. volumetric capacity[28], brooms, pans, brushes and shovels, who complete the street sweeping, collection of refuse from households and roadside heaps for an assigned area and carry the refuse to the larger vats. The work is done in an eight hour shift in the morning (from 5 A.M. to noon with a half an hour recess between 9 - 9,30 A.M.)[29] and the duty of the collection mazdoors ends with the storing of the refuse at the vats.

Because of the absence of adequate storage capacity for the refuse generated, particularly in the low income households and in the informal sector, these tend to be continuously dumped on the road. Therefore, almost immediately after the morning clearance, refuse starts accumulating on the road.

Transportation

In place of the previous truck-cum-municipal railway system to carry the refuse to the dumping site at present trucks carry refuse straight to the dumping ground. In fact, a number of mechanised transportation modes are now in operation which are :

(a) truck-truck mazdoor combination;

(b) tipper truck-truck mazdoor comibation;

(c) tipper truck-pay loader combination;
(d) roll-on-off tipper;
(e) dumper-placer-container.

In case of truck-truck mazdoor combination, a truck, accompanied by seven truck mazdoors, attend the vats where loading is done by the labourers manually[30]. Loading time required in manual loading is about 30 to 40 minutes[31]. Usually, at the dumping site, the labourers unload the truck; however, with the introduction of the tipper trucks, truck mazdoors have become redundant at the time of unloading. Tipper trucks, with mechanical unloading system, can perform a greater number of trips compared to the ordinary trucks; here the manual labour time is productively utilised only during the loading time which accounts for only a fraction of their total working hours.

In case of tipper truck-payloader combination, loading of waste on the truck is done mechanically by a payloader within about five minutes. The mechanical loading not only increase the number of trips performed by a truck (while each manually loaded truck makes, on average, three trips daily, the mechanical loading allows for 4 trips) but also raise the carrying load of each truck : each tipper truck, with a volumetric capacity about 7 cu.m., usually carries 3.5 to 4.5 tons of waste when manually loaded, but about 5.5 tons in case of loading by a payloader[32]. Besides, in tipper truck-payloader combination, manpower requirement is minimum, a truck is operated by a driver with an assistant and the payloader by an operator.

However, the mechanical loading method has one limitation : its operation requires space around the vat. In many parts of the city particularly in the old, densely developed areas and in the low income colonies and slums,

vats are on relatively narrow roads, where payloader cannot be used. Besides, often squatters' shanties are built around the vats and these make mechanical loading difficult[33]. At present, payloaders are used selectively in the areas with high rate of refuse accumulation, like wholesale vegetable mark and, sometimes, for clearing accumulated refuse. The Calcutta Corporation has introduced, in recent years, two other systems of transportation, namely, roll-on-off tipper and dumper-placer container[34].

One set of roll-on-off tipper consists of a prime-mover and five containers of 10 cu.m. capacity each. One set of dumper-placer-container consists of a tractor fitted with container carrier and containers of six tonnes capacity each. With either of these systems, the primary collection ends at the container which is placed either at the ward depot (discussed in detail below) or at selected points in the city, and the filled-in containers are carried by the prime-movers straight to the dumping ground. One of the advantages of this system is the elemination of the second handling of refuse and the costs and health hazards of the labourers associated with it. Other advantages are as follows : (a) the container being demountable the loading height is very low compared to the trucks, (b) the manpower requirement is minimum; only a driver and an assistant is required, and (c) the efficiency of the prime-mover increases as there is no unproductive confinement of it for loading of refuse or for the repair and maintenance of the container. It has been estimated that a roll-on-off tipper can easily make five round trips during a normal working day, and remove about 50 tonnes of garbage[35]. While the skps of dumper-placer-containers can be placed in less spacious location, the containers of roll-on-off tipper, being of larger size, are appropriate only for the central locations. At present, the skips of the dumper-placer-container are open

and there are some difficulties in placing garbage inside it. The Corporation is considering some improvisations, to overcome these limitations.

It may be noted here that, during the 1960s, the Corporation introduced compactor vehicles for carrying waste, and, at present, there are 20 such vehicles. However, in view of the high density of refuse, these turrs out to be not very useful[36]. The Corporation also maintains a number of night soil lorries for carrying night soil from privies.

Disposal

The third phase of solid waste management is disposal of refuse. At the disposal stage, the refuse may be processed, along with the recovery of usable materials and recycling of waste, to generate electricity, organic manure etc. While land-filling does not involve recycling as such, the other disposal methods, namely, composting, pyrolysis, and incineration etc. involve processing and recycling in various degrees. In the cities of the West, processing is required even with the land-filling method of disposal : for instance, pulverisation is required to reduce the average size of the waste material, which includes items like automobile scrap, hollow cans, etc. Baling is required to reduce the volume of an otherwise low density refuse. In Calcutta, since waste materials of relatively bigger size are usually picked up by the scavangers, and density of refuse is quite high, processing either in the form of pulverisation or baling is not required. Though in Calcutta there is no large scale mechanised recovery and recycling of solid waste, the manual recovery by individual scavangers at the city vats as well as at the dumping sites is carried out on an impressive scale. According to some estimates,

more than 5 thousand people are engaged in this occupation, and the value of the material recovered daily is no less than Rs. 161 thousand (Table 8).

In Calcutta, the predominant method of disposal is crude land-filling or, what is called, uncontrolled tipping. There is a mechanical composting plant at Bantala, set up by the West Bengal Agro-Industries Corporation with a capacity of producing about 100 tonnes of compost from an input of 200 tonnes of garbage a day, which is less than 10% of the total waste generated in a day[37]. Howeger, it is out of operation for some time mainly because of lack of demand for compost. In the early 1970s anaerobic method of disposal had been used on an experimental basis. Besides, a joint project is being launched by the Calcutta Corporation, Burn Standard Company and Central Mechanical Engineering Researdh Institute, to establish a bio-gas plant for producing methane gas from organic refuse; when operative, it would use about 150 tons of classified waste a day, and the methane gas produced will be used for power generation[38].

Coming back to the crude land-filling method, the prime disposal site is Dhape area (1696.2 acres). We have already noted that the 'Dhapa Square Mile' was acquired by the city authority as early as in 1866 and some more area was acquired in the 1970s. Two other dumping sites now under use are loacted at Bantala (with an area of 19.98 acres) and Noapara (48 acres). Besides, a small portions of the City refuse is disposed of by filling up low lying lands in Kidderpore, Tollygunge and Dunlop areas[39].

Disposal of refuse by the crude land-filling method involves various kinds of health hazard, e.g., breeding of flies and rodents, or, water pollution through leaching.

Since the river Hooghly, Calcutta's main source of potable water, is several kilometers away from the dumping area the problem of leaching is not so serious yet. However, in view of the extension of the city area towards the dumping site, the case for switching over from crude land-filling to sanitary land-filling methods has been strengthened.

One major problem with the existing dumping sites is inadequate accessibility. The absence of good road condition is a crucial bottleneck for the smooth operation of disposal work. Frequent breakdown of vehicles, low level of loading of vehicles and the inadequate number of bulldozers required for dressing the refuse, are some of the other major problems. Besides, the Noapara dumping ground can not be used during monsoon when it gets innundated[40].

Cost of Solid waste management

The solid waste management cost should include, apart from the operation costs of collection, removal and disposal, which are reported in the Corporation budget and account for about 16-20% of the total revenue expenditure, and which almost tripled between 1981 and 1987.

More comprehensive cost estimated prepared by the officials of Calcutta Corporation show that, while in 1983 cost per ton of garbage disposed was about Rs. 175, in 1988 it increased to Rs. 356 per ton, indicating that cost has doubled in five years[41]. Further the operationwise break down of the cost shows that major portion of the cost is accounted for by collection (about 68-75%), followed by transportation (20-25%) and disposal (5-6%) (Table 10). The cost of solid waste disposal in Calcutta City is higher than that for the Greater Bombay : per ton of solid waste

removed it is much less for the latter. In 1982-83 cost per ton of waste disposed, was Rs. 166 in Calcutta, compared to Rs. 115 in Bombay (Table 11).

The higher cost in Calcutta is largely due to the presence of excess manpower; while the number of worker recruited for solid waste management in Indian cities and towns is, on an average, 2.8 persons per 1000 of population, in Calcutta it is more than double that figure, about 6.3 persons per 1000 of population. Excess of labour is more visible in transportation than in cleaning and collection operations (Table 12).

One reason for this excess that, while there is no provision for superannuation, the existing system of labour recruitment, viz. 'panel system', permits the incumbent to nominate one among his kith and kin to work in his place when he is on leave or on retirement from the job[42]. Since local labour is not available for this low-graded conservancy work (which is done mainly by Harijans, mostly drawn from Chhotanagpore plateau[43]) the system ensures a stable but inflexible supply of labour and does not permit saving of labour cost even when mechanisation is introduced for unloading wastes.

The revenue expenditure on solid waste service is met from the consolidated revenue budget of the Corporation. As per the legislation, the clearance of domestic refuse is obligatory on the part of the Corporation, while charges for it is consolidated in the property tax and, therefore, not directly related to the service provided[44]. Though the Act makes it mandatory that traders pay the civic authorities for the removal of trade refuse[45], the collection of refuse-removal charges from the informal sector and small traders is beset with practical difficulties, e.g., in case of the individual traders of 'fall patty' in Burrabazar, which

generates about 8 truck-loads of garbage per day[46]. The capital expenditure for acquisition of equipment and vehicles, construction of ward depot and supply of community bins are made from the funds made available under IDA (International Development Assistance) or CUDP (Calcutta Urban Development Programme) schemes[47], but the maintenance of the assets created under these schemes is being neglected as the Corporation can not provide for it from its own funds.

IV. ISSUES RELATING TO EFFICIENCY AND EQUITY

Improvement in solid waste management may be seen as any one or a combination of the followings : (a) increase in the level of service in terms of frequency of collection and removal, sanitary and esthetic requirements etc., (b) decrease in cost at a given the level of service, (c) an even distribution of the service, with an eye on the target groups, i.e., the bustee population[48]. While the third aspect is related to equity consideration, improving service with the least possible increase in costs, or a reduction of cost of the existing service, is related to the question of efficiency.

Taking the issue of efficiency into account, solid waste management cost depends on several factors which are either outside the control of the management, e.g., the size of the city, the pattern of residential settlement and road network, climatic conditions and the socio-cultural habits of the inhabitants etc. Efficiency, therefore, should be interpreted as minimising cost after taking into account these constraints which are exogenous to the system[49].

The solid waste management system is a combination of methods applied at various stages of collection, transfer

and transportation, and recycling, and disposal. The systems differ from each other in terms of labour - equipment ratio at various stages, equipment type, organisation of the route for collection crews and transportation vehicles, disposal methods and sites. Therefore, for improvement in solid waste service intervention can be made at the following levels : (a) choice of technology and equipment, (b) organisation of the operations, specifically collection and transportation routes, (c) and overall management. However, these interventions are not mutually exclusive and should be taken together within an integrated system[50].

In view of the multiplicity of operations, even with a small number of alternatives at each stage, the total number of possible alternative systems would be many[51]. Choice from these alternatives at various levels of efficiency would involve a full-fleged operation - research exercise. Unfortunately, in view of the lack of relevant data, we do not attempt here any such comprehensive exercise; rather a broad review of the existing system of solid waste disposal in Calcutta is undertaken.

To start with the collection operation, which accounts for the major share of the total solid waste cost, it is labour intensive compared to the other operations : the ratio of wage cost to equipment cost per ton of collection is about 99:1.

Economy in cost at the collection stage can be achieved in various ways : by increasing labour productivity by way of mechanisation[52]; by reorganising the collection route, adjusting labour-equipment ratio of the collection crew and better management; or by imposing and enforcing by way of municipal regulations a reduction in the number of

dumping points and eliciting public cooperation to avoid indiscriminate dumping of waste.

Coming to the use of modern machines, in the old build-up areas with narrow lanes and by-lanes and in slums, mechanised collection operation would be infeasible. Besides mechanisation would require drastic cut in the labour force engaged in collection labour which too may not be feasible, in view of the existing 'panel system', of recruitment of conservancy mazdoors. Further, the cost of collection with machines might not be economic when per household waste generation is small.

However, there is a great deal of scope for increasing the productivity of the collection labour by way of reorganisation and better management of collection operation. It could be observed from Table 13 that there is wide variation in the productivity of collection workers across the wards. Productivity, measured by tons of garbage collected by a worker per day, depends on various factors like population density, generation rate, ratio of productive time to unproductive time of a labour - the last one depends, in turn, on the movement pattern of the collection crew and the size and type of the equipment used.

In Calcutta, a collection crew with his box-type hand cart moves from house to house or from one point of a street to another (where there is no house-to-house collection system). When the cart is fully loaded he comes to the scheduled vat for unloading the waste. Usually a number of such trips is undertaken by a collection mazdoor in the course of a day. Movement from vat to the collection site takes a lot of time, and the time so spent depends

on the route alignment and road condition. The productivity of a collection labour would be higher if density is high and/or generation rate is high. It is estimated that the variations in density, generation rate and allocation of labour per unit of area explain only about 28% of the variation in the productivity[53]. This indicates the need for a scrutiny of the existing route network of the collection crew.

Furthermore, the existing system of collection operation could not be subjected to effective management. Since the collection crew consists of three workers with one hand-cart and other instruments, there could be no separate job specification for the individual labourers. Their work load is not assessed properly; some of them engage themselves, illegally, to clean private premises during the duty hours against payment from the householders. The possibility of introducing one-man crew, with work assignment for a particular area, equipped with an improved cart, might reduce wage cost significantly despite an increase in equipment cost. Against this should be examined the risk of the work not being done in case of casual absence of the single member crew. Any change in management or technology should be coupled with an initiative to elicit public cooperation and to avoid random dumping of domestic refuse anywhere on the street at any time. Experience shows that, even if community bins are provided, these are either not used or used only improperly while the refuse accumulates outside the bin[54]. It should be noted that the Calcutta Corporation Act of 1980 provides for regulation of the site and hour of dumping household refuse. An effective enforcement of this provision alone would go a long way towards improving and economising this service.

In the area of transportation, improvement in the service quality can be achieved by eleminating further handling of garbage after its manual loading, and by using covered carriers in place of open trucks which stink, and scatter a part of the waste, along the route. As regards cost, it may be noted that per ton transportation cost depends on a number of factors, such as vehicle size, vehicle capacity, route length and route alignment, location of garbage and the method of loading and unloading. While the manual loading method can not be entirely eliminated the cost can be reduced if loading labours do not have to move with the truck to the dumping ground.

This could be done by working out a loading schedule which coordinating the movement of the loading crews with that of the transportation vehicles from one loading point to another[55]. However, given the 'panel system' of recruitment, the workers released in the process should be used productively elsewhere in order to reduce overall wage cost.

Moreover, there exists some scope for rationalising the ward-wise allocation of truck-trips. Table 14 shows wardwise estimates of garbage collection on the basis of handcarts used and also estimates of garbage removed using truck-trip figures. It is seen that the amount of garbage collected by hand-carts is less than the total capacity of truck trips used. The ratio of the estimated garbage collection to the allocated truck trip capacity varies from 130% to 35% with an average of 63%. Even allowing for the usual under-utilisation of truck-capacity, because of loading difficulties, according to one estimate, only about

72% of the capacity is used[56]. There seems to be excess of truck capacity in many wards. In absence of weigh bridges at the disposal sites, it is not possible to check whether the trucks are loaded to the capacity. Another reason may be the incompatibility of the tonnage capacity with the volumetric capacity. It often happen with low density garbage that the truck can not accommodate the garbage of capacity weight; in this case, redesigning of the trucks might be necessary. As for the movement of the trucks within the city, there is no proper route-alignment; rationalising of the movement of trucks between collection points would also reduce the cost of transportation substantially.

Transportation cost should include not only operating cost and depreciation charges for the vehicles, but also a proportionate amount of the overhead charges, including expenditure for garbages. Efficient functioning of the garrages are necessary for maintaining vehicles in good condition. Garrages should be in central locations with respect to the service area, be staffed with skilled manpower, spare parts and washing facilities. Regular washing of the solid waste vehicles, along with preventive maintenance, not only increases their life (thereby reducing the depreciation cost) but also improves the service quality, as the break-down rate declines.

According to one estimate, Calcutta Corporation has a total fleet of about 230 trucks of which only 100 to 120 are in operational condition[57]. At the time of acquiring new vehicles and instruments Corporation are garrage space and facilities and maintenance provisions are not usually take into account. As a sequence, many

sophisticated machines can not be maintained in proper order.

Ward Depot

Ward depot is the new component in the solid waste infrastructre in Calcutta, which plays the role of a primary transfer station. Under Calcutta Urban Development Programme (CUDP)-II the system of ward depot-cum-roll-on off tipper-cum-modified hand cart (carrying four container bins) has been introduced in some wards of the city. The system would satisfy three basic principles of modern solid waste management, namely, (a) refuse should not be kept open, (b) there should not be any direct body contact with refuse and (c) there should be no second handling of garbage. These norms help to improve not only service quality but also the working conditions of the solid waste workers.

The ward depot is a three-storied building, usually with an area of about 3600 sq. ft.[58]. Its ground floor houses two containers (10 cu.m. capacity each) of the roll-on-off tipper in which garbage collected in the bins are placed straight way. It also contains a store room, an open yard for storing hand-carts, the office of the ward conservancy overseer at the first floor and his residence will be at the second floor[59]. The idea behind the linking the residence of the overseer with the office is to maintain vigilence on garbage disposal round the clock.

Bins carried in the modified hand cart are placed in the street corners; households are supposed to place their refuse in the bins. Filled up bins are carried in the modified hand cart to the ward-depot, where garbage is discharged directly into the container kept there. This minimises direct body contact with the refuse and eleminates

second handling of refuse, since the filled-in containers are carried by the prime mover straight to the dumping system.

The system involves a higher level of collection cost because of the modified - hand cart[60] (Table 15) and the increased labour cost of collection as the collection crew has to travel to the ward depot in place of the road-side vats. On the other hand, the overall cost is unlikely to increase substantially, as there is no secondary collection and prime movers are used more efficiently (Table 16).

Besides the ward depot system is likely to increase overall efficiency of the system as a better supervision of collection labour would be possible now and equipments and inventory are better managed. As the ward level workers are required to report at the ward depot their performance would be more regularly monitored[61].

While, under the CUDP-II, 28 ward depots were proposed for construction, under CUDP-III, another 23 were proposed[62]. One major bottleneck in setting up ward depots is the nonavailability of suitable sites; which are located on roads which are wide enough for the movement of the container carrier.

It has been envisaged, further, that in future, when a distant disposal site would be arranged four transfer stations would be established at the peripehery of the city, from where the refuse will be carried by bulk carriers to the distant disposal site(s).

Issues regarding disposal

Though cost of disposal is less than in other operations involved in solid waste management, the issue of disposal aspect has assumed a special importance for the following three reasons : first, waste accumulates at the disposal site and thus uses one of scarce resources, i.e. land, second, environmental and sanitation issues becomes crucial with the disposal process, and, third, recovery and recycling of waste, connected with the disposal process leads to conservation of scarce resources.

In Calcutta, as in the cities of most of the developing countries, the predominant method of solid-waste disposal is uncontrolled tipping. Alternative methods of disposal, which have been either experimented with or considered are incineration, composting, anaerobic disposal and pyrolysis[63]. These methods may be compared in terms of cost involved, recycling of resources and land requirement. A method of disposal which is costlier than another in terms of direct costs may be recommended if it is found that the social gain from recycling and economy in land requirement outweighs the disadvantage in terms of direct costs. Adopting a particular method of disposal for a city for a specific time span depends on the factors specific to the city, like the physical characteristics of the city, its location, the characteristics of the garbage and the economic condition of the people. However, we do not have Calcutta-specific data for the various methods of disposal. Hence, our analysis will be based on data available for various cities of India and other developing countries.

In terms of the cost of disposal, crude land filling followed by the sanitary landfilling is the cheapest method. The available cost estimates for different methods of disposal shows that the cost of disposal methods other than landfilling is prohibitively high (Table 17). While the cost of disposal by crude tipping is not more than Rs. 5 per ton and that for sanitary landfilling is Rs. 8-15 per ton, the cost of incineration is about Rs. 200 per ton, and for mechanical composting, Rs. 80 per ton. Because of the low calorific value of garbage in Calcutta, fuel oil has to be used for incineration. While it can be used for electricity generation too, it is not clear whether this source of power would be economic compared to the other existing sources[64]. Besides, incineration has adverse environmental side effects, e.g., pollution of air.

One argument, often advanced in favour of incineration, is that it economises land requirement and, therefore, would be particularly useful in a situation of depleting disposal sites in the outskirts of the city. Otherwise, the city authority would have to use distant landfilling sites which would result in increased costs. But, it has been found that economy in land requirement with incineration method is not substantial in the cities like Calcutta[65]. After disposal by open dumping and resting within the dump for six months or so, the refuse gets consolidated to a higher density. Table 18 shows tentative land requirements for sanitary landfilling of untreated wastes compared to that for the incineration residue. It could be seen that, in a city like Calcutta, economy of space in incineration method would be only 0.3 cu.m. per ton. In fact, if we take into consideration

that part of the refuse that could be used for composting, the difference will be still lower. Moreover, it is established that the cost of disposal at a distant landfilling site (including the cost of transportation) is much lower than the cost of incineration (Table 19).

For composting, however, marketability is a big problem, which is related to the cost for compost manure and the cost of transportation involved. Coming to the cost aspect of composting one must take into consideration the complex nature of costs and benefits associated with composting and its use. Composting adds to the direct cost of disposal, but it imparts social benefit in the form of economising land required for disposal and recycling of resources. A part of this benefit is realised as private benefit in the form of increased agricultural productivity, whereas transportation cost of this bulky low value item is usually paid by the individual. Thus, from social point of view, composting will be beneficial if the total benefits from composting (whether accruing to the individual or to the society) is greater than the cost of preparing composts and the cost of transportation to the point of use. Marketability would depend on whether private benefit is greater than private costs. The higher the distance of the composting plant from the point of use, the greater would be the private cost. According to the available estimates, ex-factory price of compost produced at the mechanical composting plant at Dhapa is, approximately, Rs. 94 per ton (at 1976 prices) while the value of its NPK content is about Rs. 100, according to the prevailing market prices of chemical fertilisers[66]. Given this slender margin above the chemical fertiliser, for successful implementation of the composting scheme the location of the composting plant and low-cost

transportation arrangement are important[67]. Transportation of compost by individual small farmers may not be economic; but transportation by cooperatives would be more viable. It should be noted that, since those estimates were made, the price of chemical fertilisers has significantly increased, thus making composting even more economic, even with higher petrol/diesel charges.

Coming back to landfilling, which would remain as the predominant mode of solid waste-disposal in the coming decades, the issue which becomes immediately crucial is the availability of dumping sites. The time period for which the existing sites could be used depend on the height of landfilling. Assuming a 100 ft. height above the surface level (the height of the concrete transfer station), the National Environment Engineering Research Institute (earlier Central Public Health Research Institute) projected in 1975 an available disposal space in the Dhapa area which would have accommodated refuse for the next 125 years[68], but at the cost of the existing large water-bodies (bheries) in the area. However, the water bodies in the Dhapa area have their own merits in terms of generating employment and maintaining ecological balance and drainage of Calcutta city proper. Therefore, these should not be used as landfilling sites[69]. Secondly, the areas filled up upto the ground level are either leased out to or encroached upon by the vegetable growers and no further dumping could be made in those areas. Thirdly, in the absence of a land-use plan in the Dhapa area, the Corporation has adopted the policy of landfilling only upto the road level, which allows for a filling depth of about 7 to 8 ft. only[70]. Taking these constraints into account, it is envisaged that the

land-filling sites in the Dhapa area will be exhausted in the near future - may be within five to six years[71].

So far as the other dumping grounds are concerned, Bantala has already been exhausted and dumping at Noapara has been stopped because of metro-railway construction. It is important, therefore, that an early decision should be taken regarding the future land-use in Dhapa and the permissible height of land-filling there. If water bodies are to be protected then alternative landfilling sites should be found keeping in mind (a) the future growth of the metropolis, (b) whether it is economical to use different landfilling sites for different parts of the city so that transportation costs could be minimised. According to some official estimates, assuming an average depth of fill of 2 metres, a total of 800 hectares (including road space etc.) would be required for twenty years (from 1988 onwards)[72]; it has been suggested that, in the South-Suburban municipality, abandoned brick-fields and marshy lands of about 330 hectares[73], would be available for solid waste disposal in the southern zone. The remaining land, it has been suggested, could be acquired in the northern and eastern fringe areas. More than 1000 hectare areas have been identified as possible sites for sanitary landfilling in this sector, at Barti Bill, Bill Kana and neighbouring areas north of Barasat-Barrackpore expressway. Because of higher haulage of about 20 to 30 kms., construction of four transfer stations (at Cossipore end, at Dhapa end, near Garden Reach end and at Jadavpore end) in near future has been suggested[74], for carrying solid waste to the distant land-filling sites. It may be noted, however, that these recommendations are not based on proper cost-benefit analysis and evaluation of alternatives. In this connection, the possibility of using

water transport, which is cheaper for bulky low-value material, may be considered for carrying solid waste to distant disposal sites in the interior districts on either side of Hooghly without creating environmental pollution, particularly water pollution[75].

Management and Planning Issues

An efficient solid waste management service involves a great deal of planning and management inputs, because of the following reasons : (a) the service depends on labour-intensive techniques for collection and transfer of refuse; (b) the system requires public education and encouragement; (c) refuse collection and disposal equipments are short-lived and require regular financial planning for replacement and improvement; (d) daily preventive maintenance and ability to meet major repair needs are essential to keep the fleet on the road and can only be accomplished through good planning and procurement of spare parts and supplies and (e) there are many stages of mechanisation available; as city base line conditions and needs change, the system must be continuously responsive to those[76].

We should mention two major impedements for proper planning and management. First, is the problem of divided responsibility for various activities of refuse management. We have seen above, how, in the early 1970s, the responsibility of solid waste management operation was divided among the engineering motor vehicles and municipal railway departments. This division of responsibility not only created problems of coordination in day to day operation, but also posed serious problems for forward planning[77].

As solid waste management was not the exclusive concern of any of these departments, id did not receive proper attention in the allocation of funds[78]. Now, placing the entire responsibility with the conservance directorate, has resulted in a better coordination of various operations and in instilling initiative to improve solid waste service. For planning and management of the solid waste system, detailed upto-date data are required, e.g. on waste composition, density of waste and its variation in various parts of the city, ward-wise collection crew and their routes, daily collection of waste, the size and capacity of the vehicles used. But, there is no system of collection of these data at regular intervals. Even data which can be collected through routine administration, without incurring much expenditure, like route charts of the collection crew and the transportation vehicles, are not collected. Without proper data base, it is not possible either to identify the in-built inefficiencies of the existing system or to suggest changes.

Lastly, it may be noted that, having a modern cost-effective system of solid waste management depends on the land use characteristics of the city. Since land use pattern is not changeable in the short run, improper land use pattern may impose on the citizens a higher cost burden of solid waste removal. Further, new areas added to the city from time to time, with then with their winding lanes, narrow roads and limited accessibility present the same set of bottlenecks which are dogging the solid waste management system in the old city areas.

In this context, the need for special arrangement of solid waste collection and temporary storing in the multi-storied buildings must be emphasised. It may be noted, that the Calcutta Corporation Act of 1980 empowers the

the authority to withhold the sanction of the building plan, unless there is adequate provision for the removal or temporary disposal of solid wastes[79].

V. SOLID WASTE MANAGEMENT IN CMD MUNICIPALITIES

While the standard of solid waste management service in Calcutta city is not satisfactory, that in the municipalities in the C M D area is no better; in fact, in some relatively new municipalities, like New Barrackpore, solid waste management service is almost non-existant. The municipalities differ in size and density of population. Though there is no firm estimate of per capita generation of the solid waste in the municipalities, it is placed between 0.44 to 0.55 kg. per capita per day (Table 19). Difference in the generation rate between the smaller municipalities and the Calcutta city is primarily due to the difference between the two in the extent of commercial activities and in per capita income.

The estimated actual collection rate is much lower than the estimated generation rate (Table 19) : on an average, 47% of refuse is collected. The proportion varies considerably from municipality to municipality; while actual collection is less than 20% of generation in the municipalities like New Barrackpore (5%), North Dum Dum (6.8%) and South Dum Dum (15.8%), it is more than 80% in the older municipalities like Hooghly-Chinsurah (83.3%), Bhadreswar (81.4%), Dum Dum (81.4%) and Garulia (80.9%). The low and varying rates of collection perhaps indicate inadequate and unevenly developed solid waste services in the municipalities. In most of the municipalities there exist no house-to-house-collection system.

Only garbage from the markets are removed regularly but not the household refuse. In the absence of regular collection of household refuse, part of it is dumped by the households in the open drains or in the adjoining low-lying areas[80]; part of the waste dumped on the road-side gets scattered or is washed away by rain, particularly during the monsoon period[81].

Little is known about the physical and chemical characteristic of the waste of the municipalities in the Calcutta Metropolitan Area. However, some idea about the solid waste characteristics of the municipalities can be obtained from the data available for the smaller cities in India, as shown in Table 20. It could be observed that the proportion of the recoverable materials, like paper, metals, etc. is less in the smaller urban areas; both calorific value and the proportion of the compostable organic matter are also low because of higher ash and fine earth content.

Solid Waste Management System in the Municipalities

In the municipalities there exist no system of house to house collection. Refuse is collected from markets, open road-side heapes, vats and public bins and street sweeping. Only in recent years there has been an attempt, in some municipalities, to containerise refuse in bins and to introduce house to house collection, with only a limited success[82].

The existing system of transportation of municipal refuse, consisting of non-tipper trucks, requires second and third handling of refuse during loading and unloading. With the help of rakes and buckets, labourers pick up refuse from vats and road side dumps and place it into the conservancy trucks : refuse is unloaded again,

manually, at the disposal site. Apart from the health hazard to which the conservancy workers become exposed, the process results in a significant wastage of vehicle time, as manual loading operation takes one to one-and-half hour, involving more than one vats[83]. Though the land-filling sites are not far away and, therefore, average round-trip haul is less than six kilometres[84], the transport vehicles do hardly make more than two trips a day, which results in a higher cost of transportation.

As in the case of Calcutta Corporation, in the municipalities too, refuse is disposed of by crude landfilling methods. While only less than two-third of the municipalities have their own disposal sites (Table 20), many of the municipalities dispose of garbage by filling low-lying private lands or railway lands. According to one estimate, almost 80% of disposal of municipal refuse is done by filling up low-lying private lands[85]. In most of the municipalities the disposal site is also used as trenching ground for night soil[86].

Cost of Solid Waste Management

For municipalities, cost estimates per ton of garbage removed can be seen from Table 19. These are rough estimates, obtained by dividing the revenue expenditure on the conservancy head, shown in the municipal budgets, by the amount of garbage collected and removed per year. These estimates are under-estimates as the proportional allocation of administrative overhead costs and the depreciation charges are not included. It could be seen that the cost of solid waste management service varies to a great extent; while the average is about Rs. 156 per tonne in 1983-84, some, like municipalities of Budge Budge (Rs. 283), and Uttar Para - Kotroung (Rs. 255),

spends more, while those like Barasat (Rs. 67.1), Garulia (Rs. 74.9) and Baruipur (Rs.85.6) spend less, than-average. On an average, solid waste expenditure accounts for about 17-18% of the revenue expenditure of the municipalities.

Improvement Measures

To improve solid waste management service in the municipalities, changes may be introduced at different levels. Firstly, indiscriminate throwing of garbage on the roads must be controlled and the refuse must be containerised at the point of generation[87]. Secondly, second handling of garbages should be avoided, by replacing hand-carts or wheel barrows with container carrying pedal-tricycles. If the disposal ground is not very far, the tricycles can directly haul the refuse to the disposal site; otherwise rickshaws would carry the waste to a convenient distance, where the contents of the bins will be discharged in a skip or waiting trailer[88]. Container carrying tri-cycles, besides eliminating second handling of refuse, would be speedier than the modified hand-cart and, thus, would be economical in the low density municipal areas.

Thirdly, transportation and unloading of refuse at the disposal site could be made more cost effective if the skips are hauled by prime movers fitted with hydraulic container carrier systems with tipping arrangement. A skip can carry upto three tons of garbage per trip, and a prime mover can make five trips in a shift, thereby removing about 15 tons of refuse per day[89]. The system can be introduced in relatively large-sized municipalities.

In case of the municipalities too, a major problem is with the disposal site. Though there is no precise

estimate about the life of the existing land filling sites of the municipalities, it is envisaged by the concerned bodies that, in not-so-distant future, the municipalities would face the problem of the shortage of suitable landfilling sites[90]. Besides, many municipalities do not have any regular disposal site of their own. Apart from the issue of competing demand for low-lying land beyond the municipal boundary from pisciculture and agriculture, the spill over urban growth in the fringe areas reduces the potential landfilling site, and makes acquisition of new sites in and around the municipal boundary prohibitively costly. Moreover, the choice of land-filling site must be consistent with the metropolitan land use, drainage and sanitation, aspects involving more than one municipality. Therefore, the concept of 'shared disposal' has been mooted[91]. It has been suggested that a suitably large common land-filling site for a number of municipalities, which would be compatible with the metropolitan drainage and sanitation requirements, would be selected by some trans-municipal body like CMDA, in consultation with the concerned municipalities. The site to be selected would be away from local municipal limits, with no foreseeable prospect for urban development. Hence, the land cost will be low, There would be transfer stations at the municipal boundaries, where the municipalities transfer their refuse to bulk carriers of an independent trans-municipal agency constituted for this purpose[92]. The operating cost would be shared by the municipalities on the basis of certain norms fixed in advance. One added advantage of the distant land-fill site is that it is likely to be near near the agricultural belt, which would make composting some of the garbage at the disposal site economically viable.

Last, but not least, is the point of management. In most of the municipalities there is no separate establishment for solid waste service[93]. Workers in many municipalities do not get sufficient equipment and vehicles. As could be seen from Table 19, neither per capita expenditure on solid-waste service nor the availability of storage space in vats or public bins has any systematic relation with actual collection. This is indicative of the hypothesis that, without reorganising the administrative set up of solid waste management, larger expenditure on capital or current head, by itself, would not improve solid waste service in the municipalities.

VI. CONCLUSION

In the context of future policy formulation it is important that we see the problem of solid waste disposal from a metropolitan perspective; in future, not only the major portion of the CMA population would live in the municipalities, but there would also be a close integration of the core city with the suburban municipalities, both functionally and physically. While some of the operations of solid waste disposal, particularly collection, would continue at local level, transportation and disposal of refuse would increasingly have trans-municipal dimensions. Moreover, for a healthy suburbanisation process, the solid waste service level, in the municipalities must be upgraded to the core-city level, though that itself is not in a very satisfactory state.

It may be noted here that a metropolitan perspective of solid waste problem was lacking in the Basic Development Plan of 1966, which in fact did not give due importance to this issue.

Another important aspect, which BDP failed to emphasise, is the interdependence between the solid waste sector and other sectors, particularly drainage and land-use[94]. A regular removal of solid waste would increase the efficiency of the drainage system, be it in Calcutta city or in the municipalities. Moreover, future improvement in the efficiency of the solid waste service would be constrained unless land-use planning is done keeping in mind the needs of mechanised collection and removal of refuse.

In Calcutta, as in the cities of most of the developing countries, a large segment of the population lives in slums; who may be denied of this essential service if an all-out mechanisation programme is taken. Efficiency increase in that case, would be only at the cost of equity. Therefore, in the short run, the emphasis should be on improving the service level through better organisation and coordination of the operations, including preventive maintenance of the existing equipments. Mechanisation should be undertaken selectively, by stages.

In the long run, say, over a 25-year span, as the metropolis would grow in area and population, there would be changes in the solid waste composition and the system of solid waste management should be capable of adjusting. It is necessary, therefore, to formulate a long run plan for the solid waste sector, indicating, broadly, the possible evolution in the solid waste disposal system in terms of the mode of transportation, the modes of disposal and the disposal sites. This would help in formulating the on-going capital expenditure programmes, particularly in the infrastructure for conservancy

service in an optimal way.

Lastly, since planning is not possible without a reliable information base, a research cell should be set-up, which would systematically collect data for the solid waste sector at regular interval, analyse and evaluate the performance of the system and its equipments, and suggest the required adjustments.

NOTES AND REFERENCES

1. Assuming a density of 517 kg. per cu.m. (see Table 5).
2. Revised Budget estimate for 1986-87. See Calcutta Corporation, Budget Estimate of Receipts and Expenditure, 1987-88.
3. Total expenditure is estimated multiplying the total quantity per annum by the average cost per ton, which is computed from the data available for a subset of municipalities. See Calcutta Metropolitan Development Authority (CMDA), Report of the Working Group on Solid Waste Management, Calcutta, July 1986, Table 2.
4. See Chapter 2 of this volume.
5. According to Bustee Survey Report 1958-59 (Government of West Bengal, Bureau of Applied Economics and Statistics) per capita space available in bustee is 37 square feet. Besides, in Calcutta as per Census of India 1981, about 42% of households with an average household size of 4.2 persons live in one room (see Census of India, 1981 Series 23, Part B A &B).
6. See The Corporation of Calcutta Year Book, Calcutta, Calcutta Corporation, 1987-88, p.
7. See Calcutta Municipal Gazette, February 22, 1986, p. 871.

8. In Calcutta city about 7% of households and in the rest of Calcutta metropolitan area (Calcutta Urban agglomeration 1981) about 18% of households do not have toilet facilities (see Census of India 1981, Series 23, West Bengal, pt. 8A and B (ii) Household Tables).
9. See The Corporation of Calcutta Yearbook, 1979-80, p. 317.
10. See Calcutta Municipal Gazettee, February 22, 1986, p. 171.
11. Though, to be precise, the terms, solid waste, refuse and garbage, have different connotations, the terms are often used interchangeably. Refuse includes all kinds of wastes in solid state, excepting excreta, coming from residential, commercial and industrial areas; while garbage refers to waste food material originally intended for or associated with food for human consumption. (See, for example, A.D. Bhide and B.B. Sundaresan, Solid Waste Management in Developing Countries, New Delhi, Indian National Scientific Documentation Centre, 1983, p. 160-161.)
12. Of course, there are checkposts to check whether the vehicles are properly loaded, but the system is not adequate (see, Calcutta Municipal Gazette, August 20, 1983, p. 2912).
13. Over time per capita generation is expected to rise in terms of volume, but whether it will also increase in terms of weight, depends on the changing composition of solid waste.
14. See S. Samaddar, Calcutta Is Calcutta Corporation, Calcutta, 1975, p. 77. It may be noted whether the usual estimates of daily generation of solid waste include silt or not.

15. See S.J. Cointreau, Environmental Management of Solid Wastes in Developing Countries, The World Bank, Urban Development Department (Technical Paper No. 5) Washington, 1982, p. 11.
16. These estimates should be treated with caution, because the relation between the per capita figures to the day time population is not clear.
17. Bhide and Sunderasan (1982), op. cit., p. 13.
18. Cointreau, Op. cit., p. 13.
19. Previously Central Public Health Research Institute (CPHRI).
20. In Calcutta, the operations like storing after generation and processing before disposal do not exist and recycling in organised form is not significant.
21. The Corporation of Calcutta Yearbook, 1972-73.
22. See Government of West Bengal, Report of the Corporation of Calcutta of Calcutta Enquiry Committee, 1962 (Local Self Government Panchayat Department), Vol. I, p. 17.
23. Report of Corporation of Calcutta Enquiry Committee, Vol. 1, p. 18-19.
24. The Corporation of Calcutta Yearbook 1978-79, p. 313.
25. Calcutta Metropolitan Development Authority, Solid Waste Management for the city of Calcutta (A.K. Basu Committee Report, 1982), p. 3.
26. Directorate of Conservancy, Calcutta Corporation, 1988.
27. House to house collection is done fully in Wards 2 & 4 and partially in the following wards : 1,3,5, 7-10, 16,27,32,34-35,38,41,47,48,51,58,62,64,67-68,70,74,76, 76,78,82-83,86,89,93-95 (Information provided by Conservancy Directorate, Calcutta Corporation).

28. Calcutta Metropolitan Development Authority, Solid Waste Management of the city of Calcutta (Problems and Alternative Strategies for Disposal) (A K Basu Committee Report) 1982, p. 3.
29. Usually a collection worker do work upto 10 a.m. in his assigned area; thereafter workers in a block form a team to clean the special problem areas (see Calcutta Municipal Gazettee, February 5, 1983, p. 2711).
30. CMDA, Solid Waste Management for City of Calcutta, Calcutta, 1982, p. 3.
31. Information obtained from Conservancy Directorate, Calcutta Corporation, 1988.
32. The same as in Note 31.
33. See Government of West Bengal, First Report of the Committee on Petitions 1980-81 (On question of suitably amending the existing laws in order to prevent indiscriminate dumping or throwing of garbage and wastes in public throughfares and to compel their suitable disposal). Eighth legislative Assembly, p. 6.
34. Four sets of Roll-on-Off-Tipper was acquired during 1984-86 under IDA/CUDP-II programme; and Dumper-Placer-Container was first introduced in 1988.
35. CMDA, Report of the Study Group on Solid Waste Management, Calcutta, 1986, p. 7.
36. M.G. Kutty, 'Modernisation of Refuse Handling' Calcutta Municipal Gazettee, August 31, 1983, p. 353.
37. S. Samaddar, Calcutta Is, Calcutta Corporation, Calcutta, 1975, p. 261.
38. Information collected from Office of the Conservancy Directorate, Calcutta Corporation.
39. See Note 38.
40. See Calcutta Municipal Gazettee, February 5, 1985, p. 2711.

41. It may be noted that methodologies of these estimates are not stated.
42. S. Samaddar, Calcutta Is, op. cit. p. 52-53.
43. Ibid, p. 53.
44. See Calcutta Municipal Gazettee, September 18, 1982, p. 2630.
45. Ibid.
46. See Calcutta Municipal Gazettee, May 8, 1962, p. 2485.
47. Under IDA/CUDP/II the Calcutta Corporation acquired about 200 tipper trucks and a number of ward-depots was built, In CUDP-III, Calcutta received an allocation of Rs. 20 millions for solid waste disposal, Calcutta Municipal Gazettee, Feb. 22, 1986, p. 170.
48. According to 1979 estimate the number of registered slum dwellers in Calcutta city is about 1.25 millions (see The Corporation of Calcutta Yearbook 1979-80 and 1980-81, p. 18. In Calcutta Corporation Act 1980 special importance has been given to the improvement of civic services including garbage removal in bustees. (see Calcutta Municipal Gazettee, March 19, 1983, p. 2784).
49. Barbara J. Stevens, Handbook of Municipal Waste Management Systems : Planning and Practice, New York, 1980, p. 3.
50. Stevens, p. 22.
51. Stevens, p. 24-25.
52. See Cointreau, Environmental Management, op. cit., p. 64.
53. From a sample of 30 wards average productivity of a collection worker is estimated at 217 kg. per day with coefficient of variation about 30%. Labour productivity in collection operation is influenced by factors like population density (PD), per capita generation rate (GR), labour employed per sq.km. area (LD). To assess how these factors explain

variation in labour productivity (LP), the following regression has been estimated :

$$LP = -0.003 + 0.03PD + 0.33CR - 0.001LD$$

$$R^2 = 0.28$$

Thus more than 70% of the variation in the labour productivity remains unexplained by the above factors.

54. For an interesting account of the misuse of bins see F.A. Attarwala, Solid Waste Management : A manual, Bombay, All Institute of Local Self Government, 1986, p. 95-96.
55. In fact the tipper truck-pay loader combination operates on some such arrangement.
56. From experience it is found that only 90% of available body volume is possible to load; and loading reliability is only 80% : thus giving an overall loading efficiency as 72% of volumetric carrying capacity of the vehicle in use (see Attarwala, op.cit., p. 8).
57. Information collected from Conservancy Directorate, Calcutta Corporation, 1988, See, also, Calcutta Metropolitan Development Authority, Report of the Working Group on Solid Waste Management, Calcutta, 1986, p. 5.
58. See A.K. Chakraborty, 'Management of Solid Waste : A New Concept for Calcutta Corporation, Calcutta Municipal Gazettee, August, 1983, p. 2911.
59. CMDA, Report of the Working Group on Solid Waste Management, Calcutta, 1986, p. 5.
60. According to the experience of Corporation officials modified hand-carts carrying four-bins are found to be inconvenient in areas where road condition is not satisfactory.
61. CMDA, Report of the Working Group on Solid Waste Management, Calcutta, 1986, p. 4-5.
62. CMDA, Report of the Working Group, op. cit., p. 6.

63. In Calcutta, there were several experiments with incineration in 1863, 1890, 1892 (at Gorgacha), and 1902 (at Dhapa), all of which failed (see NEERI, op. cit., p. 63).
64. See J. Pickford, 'Solid Waste in Hot Climate', in Water, Wastes and Health in Hot Climates - edited by Richard Feachem, Michael Mc Garry and Duncan Mara, London : John Wiley, 1977, p. 342.
65. Pickford, op. cit., p. 342.
66. Government of West Bengal, Third Report of Committee on Public Undertakings 1975-76 (The West Bengal Agro-Industries Corporation Ltd.) 22nd April, 1976, p. 15-16.
67. Bhide (1982), op. cit. p. 96.
68. It has been reported that volume available for filling would be 4697.834×10^5 cft. (see National Environment Engineering Research Institute, Feasibility Studies for Alternative Methods of Garbage Disposal for Calcutta City (including short term characterisation of refuse from Calcutta), Nagpur, 1970, p. 32.
69. Calcutta Metropolitan Development Authority, Solid Waste Management for the City of Calcutta, op. cit., p. 14; see also Calcutta Municipal Gazettee, August 7, 1982, p. 2555.
70. CMDA, Solid Waste Management for the City of Calcutta, op. cit. p. 30.
71. Ibid., p. 14-15.
72. Ibid., p. 30.
73. Ibid., p. 14.
74. Ibid., p. 14-15.
75. See M.G. Kutty, 'Modernisation of refuse handling', Calcutta Municipal Gazettee, August 31, 1963, p. 536.
76. Cointreau (1982), op. cit., p. 35.
77. Cointreau (1982), op. cit., p. 37.

78. Cointreau (1982), op. cit., p. 1.
79. See Calcutta Municipal Gazettee, Vol. 50 (18), March 19, 1983, p. 2781.
80. The proportion of built-up area for the municipalities varies from 35% (Kalyani NA) to 84% (Titagarh) while for about one third of the municipalities the proportion is less than 50%
81. See J. Pickford, 'Solid Waste in Hot Climate', op. cit., p. 324.
82. In Chandernagore Municipal Corporation area, bins for storing refuse were provided to the households, but in the absence of regular collection of refuse by the municipal staff the system did not take off (Information collected through field visit).
83. Calcutta Metropolitan Development Authority, Report of the Working Group on Solid Waste Management, Calcutta July, 1986.
84. Ibid.
85. Ibid.
86. Ibid.
87. CMDA, Towards A Perspective Plan for Calcutta Metropolis : An Approach Paper, Calcutta, 1986, p. 42-43.
88. CMDA, Report of the Working Group, 1986, op. cit., p. 13.
89. CMDA, Report of the Working Group, 1986, op. cit., p. 14.
90. Ibid., p. 16.
91. Ibid., p. 16.
92. Ibid., p. 16.
93. Ibid., p. 11.
94. CMDA, Towards A Perspective Plan, 1986, op. cit. p. 43.

TABLE - 1

ESTIMATE OF THE QUANTITY OF GARBAGE PRODUCED IN CALCUTTA

(tonnes per day)

Source	Year	Estimate
1. Talukder Committee	1962	2115
2. Vincenz	1963 (June)	2200
3. Kutty	1963 (Winter)	1363
	1963 (Monsoon)	1306
	1963 (Summer)	1366
4. National Environmental Engineering Institute	1970	1604
5. Chopra Committee	1973	1600-1800
6. Samaddar	1975	2600 (-390) (Silt)
7. Calcutta Corporation (a)	1982	1800
8. Calcutta Corporation (a)	1988	2100
9. Calcutta Corporation (b)	1989	2032

(a) Estimates prepared by Chief Engineer, Calcutta Corporation

(b) Estimates prepared by Indian Statistical Institute for Calcutta Corporation

Sources - Calcutta Metropolitan Development Authority, Solid Waste Management for the City of Calcutta : Problems and Alternative Strategies for Disposal, Calcutta, 1982; S. Samaddar, Calcutta Is, Calcutta Corporation, Calcutta, 1975.

TABLE - 2

REFUSE CHARACTERISTICS IN CALCUTTA, 1972

	City	District I (North)	District II (Central)	District III (South-east	District IV (South-west)
Moisture	41.06	41.76	41.22	36.00	45.32
C/N ratio	37.41	38.77	38.82	36.31	35.76
Garbage	16.05	16.43	15.59	14.24	14.32
Leaves	13.05	12.70	13.36	13.18	15.54
Hay and Straw	6.31	6.04	6.74	7.11	5.02
Paper	3.18	3.77	2.87	3.00	3.06
Rags	3.60	3.12	3.64	4.35	3.36
Total compostable material	42.19	42.06	42.20	41.88	41.30
Ash and Earth	33.59	33.27	33.04	32.17	31.65
Ignited coal	8.08	8.07	8.79	7.17	8.13
Earthen wares	6.65	7.44	7.18	6.20	4.50
Coconut shell	4.96	3.80	4.73	5.31	5.00
Stone	1.84	1.68	1.35	2.21	1.71
Leather	0.86	1.26	0.88	1.52	0.43
Iron and Steel	10.66	0.53	0.43	1.11	0.92
Bones	0.42	0.27	0.42	0.40	0.53
Polythene	0.65	0.53	0.75	0.43	0.80
Glass	0.58	0.25	0.49	0.33	0.61
Total non-compostable material	58.29	57.10	58.06	56.85	54.28

Notes : Figures are percentages on wet/weight basis. District I including Cossipore, District II including Manicktala and District III including Tollygunge.

Source - National Environmental Engineering Research Institute (NEERI), Feasibility Studies for Alternative Methods of Garbage Disposal for Calcutta City (including short term characterisation of refuse from Calcutta City) (Previously Central Public Health Engineering Research Institute, Nagpur, 1970; quoted in S. Samaddar, Calcutta Is, Calcutta, P. 77.

TABLE - 3

VARIATION OF PHYSICAL CHARACTERISTICS OF CITY REFUSE IN CALCUTTA

(Percentage)

Type of locality	Leaves	Garbage	Hay & Straw	Paper	Rags	Plastic & Polythene	Glass
Residential Area							
a. High income	12.08	18.67	5.52	4.01	3.61	0.80	0.63
b. Middle income	11.26	16.67	5.46	3.10	3.48	0.50	0.50
c. Low income	10.18	12.85	6.40	3.82	1.20	0.87	0.31
d. Slums	10.04	16.12	7.69	2.91	4.61	0.49	0.12
Commercial Area	13.76	16.11	7.57	3.64	3.56	0.50	0.40
Market area	15.10	19.36	6.21	2.52	3.15	1.01	0.60
Industrial area	19.22	12.34	5.67	2.20	4.57	0.59	0.08

Source - NEERI, Feasibility Studies for Alternative Methods of Garbage Disposal for Calcutta City, 1970

TABLE - 4

VARIATION OF CHEMICAL CHARACTERISTICS OF REFUSE IN CALCUTTA

(Percentage)

Type of locality	PH	N	P*	K*	Organic matter	C	C/N Ratio	Moisture Content
Residential Area								
a. High income	7.33	0.52	0.55	0.40	35.07	19.45	37.5	40.52
b. Middle income	7.22	0.52	0.57	0.36	34.90	19.39	37.0	41.56
c. Low income	7.32	0.60	0.51	0.35	34.03	18.90	31.6	42.16
d. Slums	7.42	0.55	0.63	0.42	31.56	17.53	31.4	45.02
Commercial area	7.21	0.43	0.62	0.31	39.04	21.69	50.8	40.21
Market area	6.94	0.58	0.59	0.43	39.27	21.82	42.1	43.70
Industrial area	7.15	0.68	0.58	0.68	40.14	22.30	32.9	51.30

* P; phosphorus as P_2O_3; K : Potash as K_2O.

Source - The same as in Table 3.

TABLE - 5

PER CAPITA REFUSE FENERATION AND REFUSE DENSITY IN CALCUTTA AND SOME OTHER CITIES OF INDIA AND IN USA AND UK

	Generation of refuse (kg./capita)	Density (kg./cu.m in disposal site)
Calcutta	0.50	1128[a] (518 - 573)[b]
Bombay	0.49	
Madras	0.32	
U S A		476-600
U K		700

[a] After six months at the disposal site without any compaction equipment being used.

[b] On the ordinary transportation vehicles.

Source - A D Bhide and B B Sunderesan, Solid Waste Management in Developing Countries, Indian National Scientific Documentation Centre, New Delhi, 1983, P. 141-142.

TABLE - 6

REFUSE CHARACTERISTICS OF CALCUTTA, SOME OTHER CITIES OF INDIA AND USA (1971-73) AND U K

(Percentage of wet weight basis)

	Calcutta	Bombay	Delhi	Madras	USA	U K (1968)*
Paper	3.18	4.89	6.29	7.85	40-55	36.91
Plastics	0.65	2.92	0.85	0.88	2-3	1.12
Metals	0.66	2.46	1.21	0.95	6-13	8.87
Glass	0.38	0.72	0.57	0.96	3-10	9.11
Ash and fine earth	34.00	n.a.	36.00	28.00	3-10	21.89
Compostable matter	47.00	59.78	35.00	48.00	10-15	17.61

* Only house refuse

n.a. Not available

Source - A D Bhide and B B Sunderesan, Solid Waste Management in Developing Countries, Indian National Scientific Documentation Centre, New Delhi, 1983; p. 19, 189; J J P Staudinger, Plastics and the Environment, London : Hutchinson, 1974.

TABLE - 7

CHEMICAL CHARACTERISTIC OF REFUSE IN CALCUTTA AND SOME OTHER CITIES OF INDIA AND IN U.S.A.

(Percentage on dry weight basis)

	Calcutta	Bombay	Madras	U S A
Moisture	44.11	50.60	38.63	20-30
Organic matter	35.24	23.60	29.71	30-35
N_2	0.55	0.93	0.57	0.60
P_2O_5	0.58	0.89	0.48	n.a.
K_2O	0.41	0.34	0.76	n.a.
HCV (Kcal/kg)	1504	1341	1068	3330

Source - Bhide and Sunderesan (1983), op. cit., p. 21, 189-99.

TABLE - 8

RECOVERY OF WASTE MATERIAL IN CALCUTTA

Materials recovered	Composition* (Percentage of total waste weight)	Recovery rate (for 2000 MT per day) (tonnes)	Selling price (Rs./Kg.)	Value of recovered materials (Rs. '000)
1. Earthen wares and glass	3.68	72.0	0.40	28.8
2. Paper	3.37	67.4	0.40	27.0
3. Plastic and leather	1.05	21.0	4.00	83.9
4. Ragus	4.43	88.7	0.20	17.7
5. Metals	0.10	2.1	2.00	4.1
TOTAL	12.64	251.1	-	161.5

* Estimated from sample study in Dhapa area.

Source - Project report of All India Institute of Hygiene and Public Health, 1985 (Unpublished)

TABLE - 9

EXPENDITURE ON SOLID WASTE MANAGEMENT IN CALCUTTA CITY

Year	Revenue expenditure (Rs. millions) On SWM	Total	Cost per tonne (Rs.)*
1980-81 (BE)	75.13 (20.1)	372.95	102.92
1981-82 (BE)	86.76 (18.7)	464.07	118.85
1982-83 (BE)	121.22 (16.0)	755.49	166.06
1983-84 (RE)	126.66 ( )	888.16	190.85
1984-85 (RE)	141.35 (18.7)	757.11	208.25
1985-86 (RE)	163.37 (16.0)	1019.89	223.80
1986-87 (RE)	218.51 (18.1)	1207.27	299.33
1987-88 (RE)	235.04 (16.0)	1468.75	321.97
1988-89 (RE)	267.27 (17.2)	1554.45	336.12

BE : Budget estimate; RE : Revised estimate.

* Computed assuming 2000 tonnes per day generation of solid waste

Notes: (i) Figures in brackets show percentage share of expenditure on solid waste.
(ii) In recent years the Calcutta Corporation's budget publications do not show actual expenditure.
(iii) 1983-85 onward Calcutta city includes newly added, Garden Reach, South Suburban and Jadavpur Area.

Source - Calcutta Corporation, Budget Estimates (various years).

TABLE - 10

COST OF SOLID WASTE MANAGEMENT IN CALCUTTA

	Cost per tonne (Rs.)	
	1982	1988
Cost of		
Collection	120 (68.6)	265 (74.4)
Transportation	44 (25.1)	75 (21.2)
Disposal	11 (6.3)	16 (4.5)
TOTAL	175 (100)	356 (100)

Note : Figures in brackets show percentage to total.

Sources - Calcutta Corporation, Calcutta Municipal Gazette, December 10, 1983; Office of the Conservancy Directorate, Calcutta Corporation.

TABLE - 11

COST OF SOLID WASTE MANAGEMENT (COLLECTION, LOADING, REMOVAL AND DISPOSAL) IN BOMBAY CITY

Year	Revenue expenditure on solid waste service (Rs. millions)	Mid-year population (Millions)	Estimated refuse per annum* (tonnes)	Cost per tonne Rs.)
1980-81	130.6	8.2	4018	89.02
1981-82	167.6	8.3	4067	112.91
1982-83	176.4	8.6	4214	114.67
1983-84	209.0	8.9	4361	131.29
1984-85	224.9	9.2	4508	136.68
1985-86	278.6	9.5	4655	163.96
1986-87 (BE)	427.1	9.8	4802	243.65
1987-88 (BE)	378.8	10.1	4949	209.68

* Assuming 0.49 kg. per capita per day generation (see Table 5).

BE : Budget estimate

Sources : Expenditure figures obtained from Greater Bombay Municipal Corporation, Budget Estimates (Various issues); population figures estimated from Census of India 1981 data.

TABLE - 12

SOLID WASTE WORKERS PER THOUSAND OF POPULATION

	All India average (1975) (a)	Calcutta Corporation (1980) (b)	(b) as ratio of (a)
Cleaning and collection	2.3	3.4	1.5
Transportation	0.3	2.9	5.8
Disposal	0.2		
TOTAL	2.8	6.3	2.3

Sources - Government of India, Report of Committee on Urban Waste (Ministry of Works and Housing) New Delhi, December, 1975.

TABLE - 13

VARIATION IN PRODUCTIVITY OF COLLECTION LABOUR IN SOME SELECTED WARDS OF CALCUTTA, 1988

Ward	Productivity (ton/worker/day)	Population density (10000/sq.km.)	Generation rate (kg/capita/day)	No. of worker per sq. km.
1	2	3	4	5
1	0.174	3.833	0.432	94.7
2	0.186	2.675	0.500	70.2
5	0.175	1.893	0.704	76.2
6	0.201	2.507	0.656	81.7
7	0.260	6.476	0.794	197.1
8	0.188	8.188	0.610	265.6
9	0.275	7.514	0.861	235.3
10	0.323	6.954	0.719	154.5
12	0.250	4.996	0.604	120.7
13	1.179	1.667	0.485	45.1
16	0.101	6.483	0.264	168.5
17	0.380	10.340	0.828	225.0
18	0.285	10.471	0.636	233.0
19	0.250	9.133	0.589	215.3
20	0.175	8.705	0.441	219.8
21	0.253	9.560	0.753	284.0
26	0.289	10.638	0.777	286.2

TABLE - 13 (contd.)

1	2	3	4	5
29	0.159	6.156	0.609	235.4
30	0.145	11.816	0.394	320.0
33	0.186	5.752	0.412	98.6
34	0.150	4.677	0.417	129.2
35	0.179	4.427	0.462	88.6
37	0.181	8.957	0.431	212.9
40	0.269	12.265	0.752	342.3
41	0.346	12.341	0.662	236.3
82	0.191	2.349	0.843	103.6
84	0.151	4.586	0.463	140.4
85	0.101	5.061	0.247	123.4
87	0.228	3.418	0.641	95.8
88	0.179	7.726	0.388	167.5
Mean	0.217			
CV (per cent)	30.0			

CV : Coefficient of variation

Source - Computed from data collected from Borough Offices, Calcutta Municipal Corporation.

TABLE - 14

ESTIMATE OF GARBAGE IN SOME SELECTED WARDS OF CALCUTTA CITY FROM NUMBER OF HAND-CARTS EMPLOYED AND NUMBER OF TRUCK TRIPS USED, 1988 (October)

Ward No.	Hand-cart used	Estimate of garbage per day (tonnes)		
		Hand cart basis (a)*	Truck-trip basis (b)**	(a) as per cent of (b)
1	2	3	4	5
1	42	16.8	22	76.4
2	39	15.6	22	70.9
5	38	15.2	20	76.0
6	46	18.4	28	65.7
7	23	9.2	18	51.1
8	28	11.2	16	70.0
9	26	10.4	22	47.3
10	22	8.8	22	40.0
12	21	8.4	16	52.5
13	26	10.4	14	74.3
16	19	7.6	6	126.7
17	21	8.4	24	35.0
18	18	7.2	16	45.0
19	18	7.2	14	51.4
20	19	7.6	10	76.0
21	23	9.2	18	51.1
26	28	11.2	24	46.7

TABLE - 14 (contd.)

1	2	3	4	5
29	37	14.8	18	82.2
30	32	12.8	14	91.4
33	25	10.0	18	55.6
34	35	14.0	16	87.5
35	26	10.4	18	57.8
37	22	8.8	12	73.3
40	29	11.6	24	48.3
41	17	6.8	18	37.8
82	38	15.2	22	69.1
84	22	8.8	10	88.0
85	26	10.4	8	130.0
87	23	9.2	16	57.5
88	22	8.8	12	73.3
TOTAL		324.4	518	62.6

* On the basis of maximum number of trips per day, i.e., four per day. Each hand cart has capacity 100 kg as stated in the study by All India Institute of Hygiene and Public Health.

** Assuming four ton per trip.

Source - Computed on the basis of information obtained form the Conservancy Directorate, Calcutta Corporation.

TABLE - 15

COMPARISION OF EQUIPMENT COST OF COLLECTION FOR BOX-TYPE HAND CART AND MODIFIED HAND-CART IN CALCUTTA

	Box type hand-cart	Modified hand-cart with four bins
Capacity (in kg.)	100	60 (4 x 15 kg)
Price (Rs.)	1440	1200 (Cart Rs. 800, 4 bins Rs. 400)
Life (in years)	6	6 (for cart) 3 (for bin)
Annual maintenance cost (Rs.)	192	192
Cost per ton (Rs)		
for 3 trips	2.48	4.54
for 4 trips	1.86	3.41

Source - Computed from data collected from Calcutta Corporation.

TABLE - 16

RELATIVE COSTS OF REFUSE TRANSPORTATION BY TRUCK (ORDINARY) AND ROLL-ON-OFF-TIPPER

	Truck	Roll-on-off tipper
Price (Rs.)	325000	500000
Capacity (tonnes)	4	9
No. of trips per day	4	2
Waste carried per day (tonnes)	16	18
Labour required (No.)	8	1
Operation and maintenance cost per annum (Rs.)		
a. Fuel cost	23652	18921
b. Wage cost		
driver	14448	18000
labourers[1]	94430	10800
c. Repair cost	35000	50000
Amortisation (Rs.)	126785	128260
Total cost (Rs.)	294315	225981
Cost per day (Rs.)[2]	806.34	619.13
Cost per tonne (Rs)	50.40	34.40

1. Salary of the driver of an open truck is Rs. 1200/month for 3 trip duty a day and Rs. 4 for each extra trip; wage of a driver of a roll-on-off-tipper is Rs. 1500/month. A labour gets Rs. 900/month for usual 3 trip duty and Rs. 2.75 for each extra trip.

2. Assuming that the vehicle is outsheded for 365 days.

Source - Computed from data obtained from All India Institute of Hygiene and Public Health.

TABLE - 17

RELATIVE COSTS FOR VARIOUS METHODS OF REFUSE DISPOSAL

Disposal alternatives	Cost (Rs./tonne)	Remarks
1. Crude land filling[a]	2-5	
2. Sanitary landfilling	8-15	
3. Distant landfilling (with transfer station and transportation cost for above 30 km.)	30-40	Items 1-5 Under Indian
4. Pulverisation and landfilling	70	condition
5. Composting : Manual	20 (gross)[b]	
Semi-mechanised	60 (gross)	
Mechanised	80 (gross)	
6. Incineration	200	
7. Pyrolysis and other thermal processes		For United
a. Using Gas	400-700 (gross)	Kingdom,
b. Using oil	300-500 (gross)	1977
8. Anaerobic digestion	400-600 (gross)	(items 6-8)

a. Estimated using the ratio 3.3 1 between costs of sanitary and crude landfilling in India.

b. Net cost could be obtained by deducting Rs. 15 as price per tonne.

Source - Calcutta Corporation, Solid Waste Management for the city of Calcutta : Problems and Alternative Strategies for Disposal, Calcutta, 1982.

TABLE : 18

LAND SPACE REQUIREMENT FOR LANDFILLING OF UNTREATED WASTE COMPARED TO THE SPACE REQUIRED FOR RESIDUE OF TREATMENT IN DEVELOPING COUNTRIES

	(per ton of refuse)
Crude waste as collected	2.0 Cu.m.
Decomposed crude waste after six months in landfill	0.9 Cu.m.
Incineration ash	0.6 Cu.m.
Composting rejects	0.6 Cu.m.

Source - S.J. Cointreau, Environmental Management of Urban Solid Wastes in Developing Countries : A Project Guide, Washington : World Bank, 1982.

TABLE - 19

SELECTED SOLID WASTE STATISTICS IN THE MUNICIPALITIES IN CALCUTTA METROPOLITAN AREA, 1985-86

	Generation per capita (gms)	Collection per capita (gms)	Collection as per cent of generation	Cost per tonne (Rs.)	Capacity of bins/ vats per 1000 population (cft.)
1	2	3	4	5	6
Jadavpur	450	60	13.3	-	7.5
South-suburban	449	71	15.8	-	1.8
Garden Reach	542	217	40.0	-	-
Budge Budge	446	127	28.5	283.2	8.6
Baruipur	460	153	33.3	85.6	35.7
Rajpur	452	136	30.1	-	-
Baranagore	474	312	65.8	217.6	33.5
Dum Dum	440	358	81.4	-	79.2
Kamarhati	450	129	28.7	-	6.0
Titagarh	460	383	83.3	156.9	43.1
Barrackpore	457	171	37.4	159.8	80.0
Khardah	442	265	59.9	-	6.2
Panihati	448	219	48.9	96.6	2.3
Garulia	455	368	80.9	74.9	14.3
Bhatpara	452	296	65.5	126.7	26.3
Naihati	455	175	38.5	-	23.6

TABLE - 19 (contd.)

1	2	3	4	5	6
Halisahar	442	214	48.4	137.7	20.6
Kalyani NA	470	157	33.4	85.6	235.1
Gayeshpur NA	455	124	27.2	61.6	-
Kanchrapara	455	202	44.4	-	70.4
N. Dum Dum	453	31	6.8	-	-
S. Dum Dum	450	197	43.8	-	-
New Barrackpore	451	21	4.7	-	-
N. Barrackpore	443	221	49.9	-	123.0
Barasat	454	151	33.3	67.1	-
Bally	456	212	46.5	187.1	10.9
Uttarpara Kotrung	453	176	38.8	255.2	94.1
Serampore	457	236	51.6	-	-
Konnagore	462	288	62.3	169.1	20.7
Rishra	446	322	72.2	120.4	13.0
Champdani	460	263	57.2	214.3	46.8
Bhadreswar	547	445	81.4	155.7	10.9
Baidyabati	454	355	78.2	-	17.8
Chandernagore	453	217	47.9	245.0	23.6
Hooghly-Chinsura	464	387	83.4	142.5	279.6
Bansberia	456	161	35.3	-	86.9
Average	459	217	47.3	155.6*	-

* Simple average.

Sources - CMDA, Report of the Working Group on Solid Waste Management, Calcutta, 1986; expenditure on solid waste management by the municipalities collected from, Institute of Local Government and Urban Studies, Government of West Bengal.

TABLE - 20

SOME CHEMICAL CHARACTERISTICS* OF INDIAN CITY REFUSE

Characteristics	City size (in millions)			
	less than 0.2	0.2-0.5	0.5-2.0	above 2.0
Moisture content (per cent)	22.12	25.05	22.45	31.18
Organic matter (per cent)	22.01	22.51	21.51	27.57
C (per cent)	12.56	12.51	11.95	15.32
N (per cent)	0.60	0.61	0.55	0.58
P as P_2O_3 (per cent)	0.70	0.71	0.67	0.59
K as K_2O (per cent)	0.70	0.73	0.72	0.67
C/N	20.35	20.47	21.45	26.23
Calorific value (kcal/kg)	800	874	865	1140

*All values except moisture content are on dry weight basis.

Source - A D Bhide and B.B. Sundaresan, Solid Waste Management in Developing Countries, Indian National Scientific Documentation Centre, New Delhi, 1983, p. 20-21.

TABLE - 21

AREA OF DISPOSAL SITES OF THE MUNICIPALITIES IN CALCUTTA METROPOLITAN AREA, 1986

Municipality	area for dumping of refuse and and trenching (acres)
1. Baidyabati	4.5
2. Bansberia	6.5
3. Baranagar	7.0
4. Barrackpore	3.5
5. Bhadreswar	6.0
6. Budge Budge	7.0
7. Champdani	7.5
8. Chandernagore	7.0
9. Dum Dum	4.0*
10. Garden Reach	14.0**
11. Carulia	14.0
12. Hooghly-Chinsura	5.0
13. Kamarhati	6.0
14. Kanchrapara	6.0
15. North Dum Dum	2.5
16. Rajpur	6.0
17. Rishra	6.0
18. South Dum Dum	13.0
19. South Sub-urban	3.0**
20. Titagarh	70.0*

* Exclusively dumping area.

** Included in Calcutta Municipal Corporation.

Source - CMDA, Report of the working group on solid waste management, Calcutta, July, 1986.