DISCUSSION PAPER

Report No.: UDD-37

# COSTING AND COST RECOVERY FOR WASTE DISPOSAL AND RECYCLING

by

Charles G. Gunnerson
David C. Jones

January 1984

Water Supply and Urban Development Department
Operations Policy Staff
The World Bank

Charles G. Gunnerson is senior project officer for the UNDP/IBRD resource recovery project. He is a sanitary engineer with particular expertise in liquid and solid waste recycling, environmental monitoring and management. His entire career has been as a civil servant at local, state, national and international levels. He is presently on loan to the World Bank from the US National Oceanic and Atmospheric Administration.

David C. Jones is financial adviser for Water Supply and Urban Development at the World Bank. His career has been spent in various aspects of water supply, sanitation and urban financial management in the UK, in developing countries and at the Bank.

## ABSTRACT

In 1981, a three year global research and development project on integrated resource recovery (GLO/80/Q04) was undertaken by the World Bank as executing agency for the United Nations Development Programme. Project goals are to achieve environmental, employment, energy, economic, financial and health benefits through sustainable resource recovery and utilization projects and programs in developing countries. Liquid and solid waste from municipal, industrial and agricultural sources and their recycling are within the scope of the project. Sustainability in solid waste management systems depends upon a number of important policy, technical and economic interrelationships. These interrelationships, some of which are discussed in this paper, are particularly important in integrated multipurpose systems.

## Table of Contents

# COSTING AND COST RECOVERY FOR WASTE DISPOSAL AND RECYCLING

by CHARLES G. GUNNERSON and DAVID C. JONES[1]

## 1. Introduction

There is increasing recognition in both developing and industrial countries of the need for technical and economic efficiency in allocation and utilization of resources. A large body of World Bank Research has been directed to this end, including that on Appropriate Technology for Water Supply and Waste Disposal (Bank Research Project 671-46). The latter revealed a need for further research and development in integrated systems for recovery and utilization of household and community wastes.

In 1981, a three year global research and development project on integrated resource recovery (GLO/80/004) was undertaken by the World Bank as executing agency for the United Nations Development Programme. Project goals are to achieve environmental, employment, energy, economic, financial and health benefits through sustainable resource recovery and utilization projects and programs in developing countries. Liquid and solid waste from municipal, industrial and agricultural sources and their recyling are within the scope of the project. Sustainability in solid waste management systems depends upon a number of important policy, technical and economic interrelationships. These interrelationships, some of which are discussed below, are particularly important in integrated multipurpose systems.

---

1/ Respectively, Senior Project Officer and Financial Adviser, World Bank, Washington D. C. 20433.

## 2. Solid Waste Management Objectives and Technologies

Materials become wastes when their owner will give them away or pay to have them hauled away. The essential decision in solid waste management is whether to dispose of the wastes or retain the remaining values in them. This decision is being made at all levels, household, municipal and industrial. In any event, people carry more materials into their comunities than they carry out and the residual has to be dealt with. The goal of solid waste management and recycling is to conserve resources including the community space which the wastes would otherwise pollute. Solid waste management is not cheap; some developing country cities spend over 30 percent of their budgets on refuse collection and disposal.

### 2.1 Environmental Objectives and Constraints

Urban space is limited, expensive and easily polluted. The conventional approach is to collect wastes which would otherwise cause a myriad of small dispersed environmental problems and combine them into a single large concentrated environment problem. Centralized sewage and garbage disposal systems are both designed to get the wastes off the streets; they reduce the area but not the mass of pollution problems.

Annual capital recovery costs are typically two to four times the operation and maintenance costs. Total financial costs for sanitation or sewerage are from about 1.2 to nine times the cost of water supply, depending on the water service level. The higher values reflect the hydraulic costs of collection and treatment; note that the costs of treatment and collection problems are not from getting solids out of the water but from getting water out of the solids.[2] While this ratio is reversed for solid materials and products because of the much higher costs of supply, the total costs for solid waste disposal are characterically higher than those for sewage disposal. These costs are determined by the particular service levels and technologies selected.

## 2.2 Technology Options

The solid waste managment and recycling technolgies listed below are illustrative rather than exhaustive. Each is appropriate under proper site specific conditions. Waste quantities and characteristics which contribute to this specificity are listed in Tables 1 through 4.

### 2.2.1 Storage, Collection and Transport

Onsite or neighborhood storage requirements are determined by collection frequency (see Sec. 5.1). Unless affordable initial storage is available, domestic and commercial trash will be thrown (1) onto street surfaces for eventual crisis type collection, (2) into low-lying swamp or drainage areas unsuitable for building (see Sec. 2.2.2) or (3) over walls onto neighbor's property. In higher income areas, household storage in disposable plastic bags or reusable containers is feasible. In lower income areas, manually emptied covered concrete depots or bins (Freetown, Abidjan), truck-borne roll-on or lift-on boxes or farm tractor drawn

---

2/ This is completely analagous to separating, say, glass from a much larger volume of municipal refuse.

trailers which are periodically replaced with empty ones are appropriate (Kathmandu).[3]

Open or covered body trucks are generally preferred to compaction vehicles for refuse collection and transport in developing countries because the initial density of wastes is often already as high (see Table 1) as the 400 $kg/m^3$ density that the compactors are designed to produce. The higher densities of developing countries are due to inclusion of street sweepings and, especially during rainy seasons, higher moisture content.

Vacuum trucks are used for emptying and transporting nightsoil from household vaults, settled and stabilized solids from septic tanks and other sludges. Solids concentrations greater than about 10 percent cannot ordinarily be pumped. The tendency of nightsoil solids to form a thick, viscous (thixotropic) mass within about two weeks requires either collection frequencies of about ten days or fluidization by stirring or adding water or previously pumped sludge with lower solids concentrations. Long-handled shovels and buckets are generally used for heavier sludges.

Collection and transport costs usually dominate solid waste management costs. Operation and maintenance efficiencies are determined by labor wages and benefits, the ratio of collection time to haul time, truck or trailer capacity, availability of imported spare parts and skilled mechanics, average downtime for equipment, and costs of fuel and tires. Compaction vehicles are particularly vulnerable to breakdown. Hand drawn

---

3/ Reorganisation of Solid Waste Management in the Kathmandu Valley--Technical Concept for Solid Waste Management in the Cities of Kathmandu and Patan. Solid Waste Management Project, Nepal Solid Waste Management Board, Nepal and German Agency for Technical Cooperation Ltd., Germany. (April, 1983) cart and mechanized vehicle designs and capacities are fixed by street widths and grades and by the sizes of areas served.

In all cases, the short operating lives of vehicles require complete cost recovery so that equipment can be retired and replaced after about five to eight years. Meanwhile, an additional 10 to 15 percent of investment costs is required each year for equipment maintenance.

### 2.2.2 Conventional Disposal

Solid waste disposal costs in developing countries vary from essentially zero for littering or unoffical dumping into small low-lying area drainage channels to \$20 to \$60/ton for landfills with daily cover and leachate control to \$150 to \$200/ton for incineration. Investment costs for each piece of landfill equipment range from about \$40,000 to \$160,000; 10 to 15% of that is required annually for maintenance, and average life is five to ten years. Some of these costs can be applied toward resource recovery systems engineered into the disposal technology (Sec 2.2.3).

### 2.2.3 Resource Recovery Technologies

The Resource Recovery Project (UNDP/GLO/80/004)4/ is completing state of the art reviews of a number of technologies including wastewater irrigation, anaerobic digestion (including landfill gas), inorganic materials recovery, remanufacturing and advanced technologies for materials recycling. These reviews are coordinated with a number of site-specific surveys of existing waste management and recycling systems in which potential improvements in productivity are identified.

Some research and development programs currently underway include wastewater irrigation in Cyprus, land reclamation with small engineered landfills in Bangkok, wastewater aquaculture in Lima, nonferrous metals and plastics recycling in Shanghai, compost and materials marketing in Kathmandu, landfill gas in Recife, and thermophilic digestion in India and China.

Technologies listed above are applicable to wastes from one or more sources (residential, commercial, institutional, industrial, agricultural) and can deliver one or more products (energy, materials, water, land, fertilizer) as well as environmental and economic benefits. Mean-

---

4/ Base funding for the three year global Resource Recovery Project is about US$2 million. This has been generally sufficient for the state of the art studies and for limited site investigations, project identification and project preparation activites. Cost-sharing with national, bilateral, or other multinational sources is required for demonstration or investment project preparation and execution. Although the Project assists with the drafting of project documents, their submission to a development agency is on the initiative of the host country. Some agencies providing funding are IBRD, PAHO, BMZ, GTZ, CIDA, DDC, GOI and UNDP.

while, interim findings of the Resource Recovery Project confirm that single sector approaches to waste recycling such as energy, compost or materials recovery, continue to receive more government and donor support than integrated multipurpose systems.

A constraint to development of multipurpose resource recovery systems is the sectorial separation of costs and benefits. Often the utility (refuse disposal agency) pays most of the accounting costs while other sectors (agriculture, industry) receive most of the benefits of recycling.

Both state of the art and site-specific projects are essentially preinvestment studies whose benefits to governments include: (1) identification of policy options in materials, energy, health, urbanization and waste management; (2) increased productivity of land and people; (3) minimum costs of staged construction for rural, urban and environmental sanitation; (4) technical cooperation with other developing countries; and (5) support for stewardship of resources and the environment with benefits increasing in the future.

### 2.2.4 Technology Interrelationships and Constraints

Many waste collection and transport technologies and service levels are interrelated with resource recovery infrastructures and operations. Some of the linkages and tradeoffs are listed below:

(1) Daily collection is required for recovery of edible garbage for direct feeding to animals or for processing into pelletized

animal feed while twice weekly collection is sufficient for fly and odor control.

(2) Competition for recyclable wastes occurs at all levels (households, hawkers, collection crews, scavengers, municipal workers). Compaction trucks reduce recycling efficiencies of crews and scavengers but would not affect heat recovery from incinerators.

(3) Collection and transport efficiencies and tidiness can be increased in commercial areas by use of compaction trucks, but recycling efficiencies are reduced. An extreme proposal to eliminate the untidiness of scavenging at a major municipal dump was to shred the refuse to the point where manual picking and sorting would be impossible (shredding to this size would cost some $50 to 100/ton).

(4) Baling refuse can extend landfill space but can cause overloaded trucks and provide dump scavengers with wire or metal banding for the taking.

(5) Energy recovered as digester biogas is not available in slurry used as animal or fish food supplement. However, energy can be added to dewatered slurry by sprouting maize in it which is then fed (roots, substrate and sprouts) to animals.[5/] Alternatively,

---

5/ An Integrated Approach to the Thermophilic Anaerobic Digestion of Manure, Crop Waste and Night-Soil for an Integrated Resource Recovery Waste Recycling Project in a Village. Research & Development Institute, Kibbutz Industries Association. Tel-Aviv. (November 1982) about 30 percent of the gas can provide thermophilic (55-60°C) temperatures which increase gas generation rates (and decrease needed reactor volumes) and provide a sterile, easily handled slurry.

These and other tradeoffs lie at the roots of many constraints to recycling. Advantages of municipal scale operations may sometimes be possible in market economies, but they attract attention and suggestions that revenues be used to lower taxes. In other words, people resent others making money from what they have discarded as worthless. Other constraints include the previously mentioned sectoral separation of costs and benefits; development agency preference for complete elimination of health risks by conventional industrial technologies for a few (to provide an "example") rather than reduction of health effects among the many; and reluctance of local government and development agency officials to recognize and improve productivity of informal sector resource recovery systems and institutions.

In spite of the constraints, there are examples of integrated systems for resource recovery. These range from household and community biogas systems throughout much of Asia, which provide energy, environmental, fertilizer and health benefits, to the production of garbage bags from recycled plastic in Rome refuse.

## 3. Cost Control and Recovery

The questions of cost control and cost recovery for solid waste removal, disposal and recycling are complex. The more obvious disciplines of cost accounting and economics must necessarily be tempered by those of engineering, physical, environmental, social and political sciences. Much has been demonstrated and discussed regarding cost effective or revenue earning elements within solid waste management systems. Rarely, to date, has it been demonstrated that a potential exists for making the solid waste management process commercially profitable in its entirety. Thus, as a starting hypothesis, it is reasonable to assert that solid waste management represents a net cost to a community, which it seeks to minimize by efficiency of operation, enhancement of revenues from collection and disposal services, improvements in productivity of recycling practices already in place and the introduction of appropriate technologies for additional recycling.

## 3.1 Financial and Economic Background

A useful starting point in looking at the financial and economic aspects of the solid waste service is the acknowledgement that, to a household or firm, solid waste represents an asset of negative value. This is in spite of the fact that much of the original value can sometimes be returned by appropriate methodology. The household or firm may be prepared to pay a price to have the solid waste removed from its own premises as an alternative to the nuisance of keeping it. However, the household or firm will not necessarily be prepared to pay the full cost of its removal, transportation and disposal because its perceptions of satisfaction will almost certainly be different from those of the local community. The charge (if any) which the household or firm is willing to pay will depend upon what is socially acceptable or legally enforceable. For example, in many communities, in developing and industrial countries alike, examples abound of liquid, solid, pathogenic, toxic and other wastes being dumped into streets, drains, unused ground, waterways and countryside as well as being allowed to accumulate on the users' own property. A particularly prevalent problem in developing countries is the clogging of drains with garbage. This is clear evidence of the gap, which can be measured in monetary terms, between the perceived benefits to waste dumpers and those of the community at large. The solutions which present themselves are those already commonly in use, described below.

If costs of waste management systems are recovered mainly by the levy of local taxes, households and firms are encouraged to maximize their use of the service. They are also forced to pay for it, whether they use it or not. On top of this, charges can be levied, usually upon industrial and commercial enterprises, as additional contributions towards extra costs incurred in the collection and disposal of especially heavy or offensive loads. These direct charges, like property taxes, tend to be arbitrary because of the difficulty of measuring the quantity and quality of wastes. Furthermore, these additional waste services are likely to be used and paid for directly only to the extent that there are no viable (legal, cost effective and socially acceptable) alternatives.

### 3.1.1 Taxes

It is, perhaps, futile to argue the merits and demerits of particular tax systems relative to solid waste services. In general, it is unusual and unnecessary to earmark particular local taxes to specific services. Even when this is done for legal or administrative reasons, it has little economic merit. However, two important local taxes should be looked at briefly from a philosophical or psychological point of view: property taxes and sales taxes.

Because solid wastes originate on properties, it is reasonable to perceive at least three important relationships to the provision of service. First, in the absence of massive exemptions, a tax on each property at least ensures that each occupying household or firm makes a contribution to local services, including solid waste disposal. Second, there is likely to be at least a rough relationship between the size and value of a property and its capacity to generate solid wastes. Indeed, uncollected wastes are highly likely to affect the property values, albeit belatedly. Third, the system is likely to be consistent with social equity concerns in that low value properties may well house large families with a high garbage producing potential.

Sales taxes focus attention on the fact that solid wastes ordinarily originate as purchases. This is especially so in those consumer societies where packaging represents a major portion of the bulk of commodities purchased in stores. Thus, municipal sales tax collects the cost of disposal as part of the original purchase, in a manner somewhat analagous to the levy of sewerage surcharges on water usage.

## 3.2 Commercial Opportunities—Costs and Benefits

Within this generalized framework of overall solid waste management it is appropriate to consider the commercial opportunities which have been found useful or which could be exploited in the management of solid wastes.

Sometimes wastes have no value to households or firms because they are unable or unwilling to convert these to marketable commodities. A good example would be unserviceable cars and machinery. A scrap merchant, however, may well be prepared to pay for such items in order to remanufacture them or sell the parts. This provides for removal of limited categories of solid wastes and recycling on a commercial basis. The used car "graveyards" sometimes created occupy valuable land space, presumably allowed for in the cost of the operation. However, the eyesore usually created might be regarded as an environmental cost to the community, perhaps also reflected in the depleted value of adjoining property.

A most unsatisfactory situation may arise when households or firms (especially industries creating objectionable wastes) contract to have their wastes removed commercially. The original household or firm may be completely indifferent to the ultimate disposal. The contractor, in turn, may be indifferent to its obligation to dispose of the wastes in an environmentally or socially acceptable fashion, concerned instead only with profit maximization. In such cases the households and firms are merely paying the contractor to create a public nuisance elsewhere or even to break the law—either being social costs.

Collection of solid wastes by entrepreneurs or commercial firms, with charges levied directly upon households and firms, can be done profitably only when the community is well motivated or has regulated environmental standards and is willing and able to pay to have wastes disposed of in an acceptable fashion. This situation is not necessarily confined to affluent neighborhoods. Even slum areas may be prepared to pay to keep the area clean on the basis of community participation in low cost arrangements. The motivation, in this case, is lack of space for garbage, peer pressure and the promise of better services as a reward for civic responsibility. It may also be that low cost efforts result in readily perceived improvements to a largely deprived community. Some communities encourage commercial waste collection by providing free or subsidized disposal facilities. In these circumstances, the household or firm pays the additional costs, via local taxes, to maintain the disposal facilities.

A commercial collection firm has an option of establishing facilities to enhance profits through the sale of recycled wastes. It will adopt this practice only if its marginal revenues from sales exceed the marginal costs of recycling. A high proportion of recycling costs are for sorting. Least cost sorting depends upon the socioeconomic situation of the community. In a consumer oriented "throw-away" society with relatively high labor costs, hand sorting of wastes is likely to be difficult and expensive to encourage unless special motivation exists, such as "paper drives" for charity. By contrast, where labor costs are relatively low and there is material scarcity, manual sorting may be easier to encourage. One example of this is an informal but effective system of small scale enterprises in Cairo. A hereditary guild of garbage collectors (Zabaleen) are commissioned by middlemen (Moalem) to collect garbage which has sufficient value to sort and recycle. However, they are highly selective and generally only take garbage which has commercial potential. This usually comes from middle or upper class households, leaving the poor with no service. Another, more disciplined, example comes from Shanghai, China, where households and commercial establishments are paid according to posted schedules for recyclable materials brought to municipal redemption centers.

## 3.3 Public Services—Private Contracting

Shifting from commercial services provided directly to households and firms, we now consider those provided to solid waste management authorities. In this case, the authorities employ private contractors to perform all or part of the services otherwise provided directly. For example, an authority might contract out the collection services, disposal operations and/or recycling operations. There are several advantages claimed. For example, a commercially oriented firm, working for a fee, may be more economically efficient than direct labor operations, especially where the latter are highly unionized. Also, there may be much lower administrative overhead costs when the work is contracted out. Sometimes

the claimed benefits may be only temporary or illusory. It may well be possible, through good management and incentives, to bring about significant efficiencies within the solid waste authority itself. Furthermore, it must be recognized that solid waste handling equipment is usually highly specialized. An authority which divests itself of ownership of such equipment to the private sector in the interest of "privatization" may well find itself at a later stage being held to ransom, as it were, by a private sector monopolist who then owns all the available equipment.

When contracts are let for collection or disposal management, there will be a net cost to the authority, as in any other normal contractual relationship. For recycling, the situation may be different. This is because recycling is normally an alternative to other forms of disposal. Alternative disposal systems are likely to require land (e.g., for tipping or dumping) and/or equipment (e.g., incinerators). Thus, even if a recycling contract has a gross cost to the authority there may be a net economic cost saving against the alternatives. Furthermore, the recycling, by itself, may be a profitable commercial operation. Thus in seeking competitive bids, the authority may be able to seek a net income to itself rather than a net loss.

## 3.4 Financial Management

Sound financial management of solid waste systems demands good financial analysis supported by cost accounting. Because the service is not usually fully revenue earning, investment decisions normally should be made on the basis of the "least cost feasible solution." Given that the primary purpose of solid waste management is still that of household and community sanitation, alternatives should be compared on the basis of estimated net present values, including costs of land, equipment, operations and maintenance as well as offsetting revenues from recycling. The social and environmental costs, to the extent not given monetary values, will need to be judged in terms of "minimum acceptable standards." This may be done either by discarding from analysis *a priori* all schemes not meeting such standards or else by judging *ex poste* estimated incremental costs (net of monetary benefits) against expected environmental or social impacts (or improvements). These perceived, if unquantifiable, benefits must not be absolute standards for which the solid waste entity is merely presented a bill. They must be judged in terms of affordability to the public authority, users and taxpayers with particular reference to the marginal impact on limited available overall local resources.

The efficient running of a service, once established, requires that cost controls be exercised using appropriate accounting standards for estimating, budgeting and recording. The use of well prepared accounting information will greatly assist in short term management decisions, particularly as regards optimization of the use of labor and equipment. Unfortunately, many municipal accounting systems do not produce the information necessary to facilitate good financial management or else produce it tardily and poorly presented. Furthermore, the cash accounting or fund accounting systems commonly in use often give inadequate emphasis to the costs of using expensive equipment—a significant shortcoming. There is much scope for improvement in these matters. Of particular concern is the necessity to generate adequate cash flows from taxes and charges to ensure that the relatively short-lived equipment used in solid waste management will be promptly and regularly replaced. Undue reliance upon external debt or other forms of aid or even upon government grants to sustain these operations is a recipe for disaster. We must look instead to careful management of likely available local resources.

This suggests a warning to those engaged in the development and sale of sophisticated equipment for the management of solid wastes, including recycling. Such equipment may often require operation and maintenance skills unlikely to be available in many developing countries. Furthermore, such countries may well lack the material and financial resources to ensure that the equipment is adequately repaired, much less replaced. Thus, an overagressive supplier may well have much more to lose in terms of a long term business reputation than it may gain in short term profits. There is enough "modern" solid waste equipment lying idle or underutilized in developing countries to attest to this concern.

Examples of financial information required for successful long term management are listed in Table 5. Not all of this information will be available from a cost-accounting system. Some will be used to supplement the costing system, depending upon which decisions are at issue. For example, capital investment decisions will require different analysis from operating decisions. Frequently, physical statistics will be as useful as financial information.

The recording, assessment and presentation of financial information requires a sophisticated blend of art and science, as with engineering. However, as with engineering data, financial information has its limitations and can be bungled in the hands of the unskilled. Unfortunately, necessary financial skills are often in short supply in developing countries. There is thus a danger that overly sophisticated engineering will be combined with crude financial data to produce suboptimal decisions.

The information presented in Table 5 is merely a list, therefore, and not a system. It needs to be in the hands of a seasoned financial specialist who knows what to select and to discard for any particular purpose.

## 4. Technology Selection

Selection of waste management and recycling technologies which can be replicated within or among developing countries is based on service levels, manpower and equipment availability and efficiencies and costs.

## 4.1 Service Levels

Conventional engineering masterplans and feasibility studies lead by staged implemetation of uniform minimum service levels throughout a city or other project area. However, minimum cost solutions are those in which capacity most closely matches demand. Demand in solid waste collection and disposal varies according to population densities, income levels and seasons, which are reflected in waste quantities and characteristics. Demand in waste recycling systems varies both seasonally and in response to longer term economic trends. Demand changes can be accomodated by variable service levels in collection frequency, convenience, storage at household, depot or terminal locations, manpower and equipment utilization and in equipment maintenance and service life. All of these are interactive,and all are affected by operational constraints including access (street widths and grades), traffic congestion, noise and costs of fuel tires and maintenance.

## 4.2 Technology Options

Generic listings of waste storage, collection, transport, disposal and waste recycling technologies are presented in Tables 6 and 7. The lists are representative rather than exhaustive. They are based on systems which have been placed in operation although some of them have been abandoned. Item 1.5 on Table 7, "Alchemy and hypertechnology," is included to provide for capital intensive adaptation of aerospace technologies, special enzymes, advanced numerical modelling and control systems, and other schemes for which marginal benefits have not been shown to exceed marginal costs.

## 5. Summary

Research, development, demonstration and investment projects in municipal waste disposal and recycling are of increasing importance in both developing and industrial countries. Current UNDP supported research and development in integrated resource recovery being executed by the World Bank reveals that single purpose systems for recovery of energy, water, compost, metals, etc., continue to receive more government and development agency support than integrated cross-sectoral systems. There are exceptions. For example, in a part of Cairo, integrated entrepreneurial systems for domestic refuse recycling are in place. In Shanghai, municipal integration of supply and recovery of resources from industrial, commercial, residential and governmental scrap is in effect. Major ongoing research and development includes demonstration project preparation in Cyprus, advanced biogas technologies in India, plastics and nonferrous metals recovery in China and waste fed aquaculture in Peru.

Technologies and costs for solid waste collection and disposal both constrain and are constrained by resource recovery objectives and practices. Identification and assessment of information needed for complete costing and cost recovery for both the utility and the economy is essential. A vital first step is the establishment of efficient cost-accounting systems. This, however, is not enough. Decisions regarding the appropriateness and efficiency of waste disposal systems must be based upon cost minimization or benefit maximization from an economic and social viewpoint. This necessitates financial and economic analysis which will challenge and, if necessary, override accounting conventions, budgetary procedures and single enterprise financial objectives when these prove inappropriate to an integrated approach.

Several factors create additional difficulties. It is seldom easy to levy direct charges upon users or beneficiaries of the service; benefits (and even some costs) are difficult to quantify. Surrogates or taxes must often be substituted, limiting both the effect and the analysis of market forces.

## TABLE 1

### GENERALIZED QUANTITIES AND CHARACTERISTIC OF URBAN REFUSE
(after Cointreau[6])

| | Quantity kg/cap/day | Density kg/m³ | Percent Moisture |
|---|---|---|---|
| Industrialized countries | 0.7 to 1.8 | 100 to 150 | 20 to 40 |
| Middle income countries | 0.5 to 0.9 | 200 to 400 | 40 to 60 |
| Low income countries | 0.3 to 0.6 | 250 to 500 | 40 to 80 |

## TABLE 2

### COMPOSITION OF URBAN REFUSE (in percentage by weight)
(after Cointreau[6])

| Type of Materials | Brooklyn, N.Y. (62) | London, England (63) | Rome, Italy (64) | Singapore (65) | Hong Kong (66) | Medellin, Colombia (67) | Lagos, Nigeria (68) | Kano, Nigeria (69) | Manila, Philippines (70) | Jakarta, Indonesia (71) | Lahore, Pakistan (72) | Karachi, Pakistan (73) | Lucknow, India (74) | Calcutta, India (75) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Industrialized | | | Middle Income | | | | | | Low Income | | | | |
| Paper | 35 | 37 | 18 | 43 | 32 | 22 | 14 | 17 | 17 | 2 | 4 | <1 | 2 | 3 |
| Glass, ceramics | 9 | 8 | 4 | 1 | 10 | 2 | 3 | 2 | 5 | <1 | 3 | <1 | 6 | 8 |
| Metals | 13 | 8 | 3 | 3 | 2 | 1 | 4 | 5 | 2 | 4 | 4 | <1 | 3 | 1 |
| Plastics | 10 | 2 | 4 | 6 | 6 | 5 | - | 4 | 4 | 3 | 2 | - | 4 | 1 |
| Leather, rubber | - | - | - | - | - | - | - | - | 2 | - | 76 | <1 | - | - |
| Textiles | 4 | 2 | - | 9 | 10 | 4 | - | 7 | 4 | 1 | 5 | 1 | 3 | 4 |
| Wood, bones, straw | 4 | - | - | - | - | - | - | - | 6 | 4 | 2 | 1 | <1 | 5 |
| Non-food total | 74 | 57 | 29 | 63 | 60 | 34 | 21 | 35 | 40 | 15 | 27 | 4 | 18 | 22 |
| Vegetative, putrescible | 22 | 28 | 50 | 5 | 9 | 56 | 60 | 43 | 43 | 82 | 49 | 56 | 80 | 36 |
| Miscellaneous inerts | 4 | 15 | 21 | 32 | 31 | 10 | 19 | 22 | 17 | 3 | 24 | 40 | 2 | 42 |
| Compostable total | 26 | 38 | 71 | 37 | 40 | 66 | 79 | 65 | 60 | 85 | 73 | 96 | 82 | 78 |
| TOTAL | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

Note: The above values have been rounded to the nearest whole number, unless the amount was less than 1.0.

---

6/ Cointreau, Sandra J. Environmental Management of Urban Solid Wastes in Developing Countries—A Project Guide. The World Bank, Urban Development Department. Urban Development Technical Paper Number 5. Washington, D.C. (June 1982)

TABLE 3

QUANTITIES OF ADULT HUMAN FECES
(after Feachem et al[7])

| | Urban | | Rural | |
|---|---|---|---|---|
| | Avg kg/d | Range | Avg kg/d | Range |
| U.K. general | .12 | .04 to .25 | - | - |
| vegetarian | .22 | .07 to .49 | - | - |
| USA | .14 | - | - | - |
| Peru | - | - | .32 | .06 to .65 |
| Kenya | - | - | .52 | - |
| Uganda | .18 | .05 to .35 | .47 | .18 to .98 |
| India | .31 | .02 to 1.5 | - | - |
| Malaysia | .16 | .04 to .30 | .45 | .26 to .58 |

TABLE 4

COMPOSITION OF ADULT HUMAN FECES AND URINE
(after Feachem et al[7])

| Item | Feces | Urine |
|---|---|---|
| Quantity (wet) per person daily | 100 to 400 g | 1.0 to 1.31 kg |
| Quantity (dry solids) per person daily | 30 to 60 g | 50 to 70 g |
| Moisture content | 70 to 85% | 93 to 96% |
| Approximate composition (percent dry weight) | | |
| Organic matter | 88 to 97 | 65 to 85 |
| Nitrogen | 5.0 to 7.0 | 15 to 19 |
| Phosphorus (as $P_2O_5$) | 3.0 to 5.4 | 2.5 to 5.0 |
| Potassium (as $K_2O$) | 1.0 to 2.5 | 3.0 to 4.5 |
| Carbon | 44 to 55 | 11 to 17 |
| Calcium (as CaO) | 4.5 | 2.5 to 6.0 |

---

7/ Feachem, Richard G., David J. Bradley, Hemda Garelick and D. Duncan Mara. Appropriate Technology for Water Supply and Sanitation—Health Aspects of Excreta and Sullage Management: A State-of-the-Art Review. The World Bank. (June 1981)

TABLE 5

EXAMPLES OF FINANCIAL INFORMATION FOR SOLID WASTE MANAGEMENT

A. Financial Information Likely to Be Available from the Accounting System of the Solid Waste Management Unit or its Parent Entity.

1. Capital expenditures on land, disposal and recycling plant, vehicles, equipment, transfer stations and operational and administrative premises.

2. Recurrent cash expenditures on labor, power and water, rent, vehicle hire, contractual services, supplies, interest and debt repayment.

3. Capital receipts from fixed asset disposals, loans (including terms), grants and land sales.

4. Recurrent receipts from taxes (collectibles and collected), charges to households and firms (for collection, use of tip, etc.), fines for unauthorized dumping and sales of recycled products.

5. Imputed or assessed costs for use of inventory, depreciation, labor overheads, administrative overheads, pooled plant expenses and provision for debt amortization.

B. Financial Information Unlikely to Be Available from Accounting System of the Solid Waste Unit or its Parent Entity.

1. Replacement costs of vehicles, plan and other short lived assets.

2. Opportunity costs and disposal values of land for initial purchases and for final disposal on closure of controlled tips.

3. Discount rates for DCF calculations.

C. Supplementary Physical Statistics.

1. Working lives of fixed assets and depletion lives of controlled tips.

2. Inventory of equipment giving sizes, load capacities and limits of working with restricted access.

3. Collection and disposal statistics, including tons collected and disposed of and route mileages for collections and haulage to tips.

4. Labor hours, including productive and unproductive.

5. Outshedding times of vehicles and information on repairs and maintenance, including down time.

6. Comparative operating statistics (and reliability) of different types of vehicles and plant.

7. Numbers of premises served by type and locality.

D. Monitoring Indicators.

1. Costs per load, per ton, per mile, per ton-mile, per household/firm, per labor unit, per vehicle type, etc.

2. Tax and user charge recovery rates in relation to sums collectible.

3. User charges (by type of premises, waste product or locality) in relation to imputed costs of service.

4. Timewise comparison of cost components.

5. Revenues from recycling sales relative to costs of recycling.

6. Vehicle running times to dumps relative to collection times.

**TABLE 6**

**A GENERIC CLASSIFICATION OF SOLID WASTE MANAGEMENT TECHNOLOGIES**

1. Storage
1.1 On-site
- disposable containers
- reusable containers
- roll-on or lift on containers
- piles or open bins

1.2 Off-site
- tossed onto nearest street
- open or covered bins
- open trailers
- roll-on or lift-on containers

2. Collection
2.1 On-site
- door-to-door pickup
- curbside pickup

2.2 Off-site
- brooms, shovels and carts
- front-end loaders
- mechanized street sweepers

3. Transport
- hand or animal drawn carts
- farm tractor drawn trailer, open or covered
- trucks, open or covered
- compaction trucks (solid wastes)
- vacuum trucks (liquids or sludges)

4. Transfer Stations
- gravity transfer of solid wastes
- pumped transfer of sludges

5. Transfer Vehicles
- large tractor-trailer combinations
- barges (requires unloading or second transfer station)

6. Disposal
- littering or dumping into small depressions or channels
- engineered, rapid filling of small depressions or channels
- open (usually burning) dumps
- landfills with daily cover
- incineration with quenched ash disposal into dumps or landfills

**TABLE 7**

**A GENERIC CLASSIFICATION OF RESOURCE RECOVERY TECHNOLOGIES**

1. Inorganic Materials Recovery
1.1 Reuse, repair, remanufacturing
1.2 Manual sorting and classification (with or without picking belt and magnetic pulley)
1.3 Mechanical preparation, sorting and classification
1.3.1 Shears
1.3.2 Shredding and grinding
1.3.3 Trommels and screens
1.3.4 Magnetic separation
1.3.5 Eddy-current separation
1.3.6 Air classification
1.3.7 Liquid classification (float/sink, hydroscopic/hydrophilic, heavy media, etc.)
1.4 Processing
1.4.1 Ferrous metals—cold refabrication, foundrig electric furnace
1.4.2 Nonferrous metals—cold refabrication, chemical separation and purification, ingots or industrial grade chemicals), realloying
1.4.3 Thermoplastic polymers—heat and pressure reforming
1.4.4 Thermosetting polymers—pyrolysis/cracking back to monomer and reconstituting
1.5 Alchemy and hypertechnology
2. Organic Materials Recovery
2.1 Composting
2.1.1 Aerobic (batch or continuous; windrow, enclosed bins or reactors)
2.1.2 Anaerobic (batch "moldering")
2.2 Anaerobic digestion
2.2.1 Ambient, mesophilic ( 35°C), thermophilic ( 55°C)
2.2.2 Low (4-12%) solids in feed
2.2.3 High (18-24% solids in feed
2.2.4 Landfills (controlled moisture)
2.3 Hydrolysis and fermentation
3. Energy Recovery
3.1 Direct combustion
3.1.1 Dung, crop offal, etc., for cooking and heating
3.1.2 Heat recovery form incinerators
3.2 Biogas (see 2.2)
3.3 Energy equivalents in recovered inorganic materials
4. Protein, Humus and Fertilizer Reclamation
4.1 Direct refeeding
4.2 Indirect refeeding
4.3 Agriculture and aquaculture (see 5.)
5. Wastewater Reclamation
5.1 Sewage farms
5.2 Effluent irrigation
5.3 Aquaculture (ponds for effluent maturation, fish, prawns, algae, etc.)
6. Land Reclamation
6.1 Small, neighborhood scale for early completion
6.2 Large metropolitan