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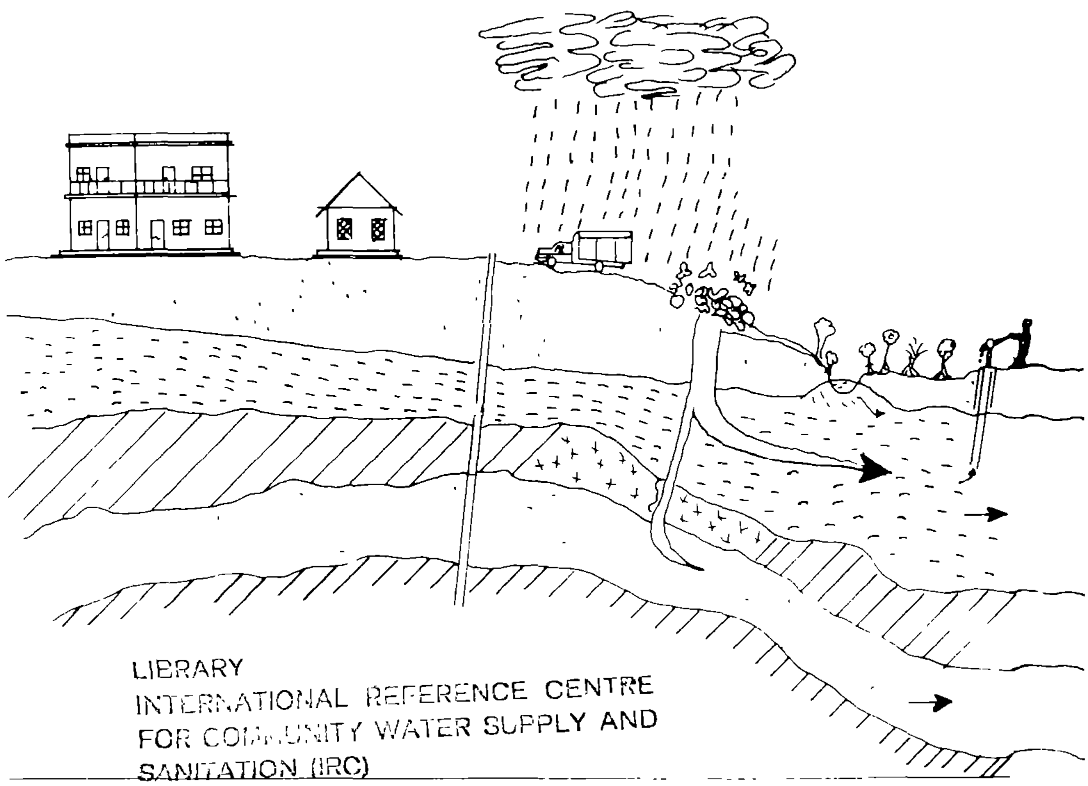
Ngainayo Colman M.

Disposal of Solid Wastes in Moshi and Arusha Towns, Tanzania



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DISPOSAL OF SOLID WASTES IN MOSHI AND ARUSHA TOWNS , TANZANIA

by

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Thesis submitted to the department of civil engineering, Tampere University of Technology in partial fulfilment of the requirements for the degree of Master of Science in Engineering

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Moshi, Tanzania

DISPOSAL OF SOLID WASTES IN MOSHI AND ARUSHA TOWNS, TANZANIA

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ABSTRACT

Moshi and Arusha towns are located in the northeastern part of the United Republic of Tanzania. Similar to other towns of developing nations, solid waste management is not yet well established, and therefore the existing data is very limited. Often 40 to 60 % of the waste is uncollected. The generation rates and composition of solid wastes vary from place to place. Some solid wastes are hazardous and require special disposal consideration.

There are various methods of solid waste disposal. Due to the limited financial resources including limitation on foreign exchange, crude open dumping is the final method of solid waste disposal in both of the towns. Problems exist with standardized containers, and therefore non-standardized containers at the point of generation are used in many places of both towns as a storage for the solid wastes. Mainly side loading non-compacting trucks collect and transport the wastes to the disposal site.

The risk of environmental pollution associated with solid waste mismanagement is high and the effects of polluted water sources are many. Analysis of water samples from sources near the dumping site in Moshi town indicates a possible interference particularly during the rains.

Both towns are subjected to a low budget ceiling. This necessitates proper planning and periodic reviews of the solid waste management system in order to incorporate new ideas resulting from implementation constraints.

1 INTRODUCTION

Man generates solid wastes in his daily activities. Processing and non-processing industries generate solid wastes. All these need to be disposed off to avoid environmental degradation and eyesores like aesthetic nuisance, odours, flies, rats etc. to the general public.

In towns and cities of developing nations, such issues and problems as high growth rate (usually 4 - 7 % per year), enormous deficiencies in basic services and poor maintenance and operation of assets make these rapidly growing urban centres better today than tomorrow.

Administrative authorities in these towns wish to have a facility like a sanitary landfill, but the expensive vehicles and mechanical equipment required do not balance the available resources.

Recycling is in the hands of informal sector entrepreneurs who at the lowest level live in settlements near the refuse dumping grounds and it is not recognized.

The priority in managing solid wastes in these towns is to remove the refuse from the town centres to the dumping sites by providing affordable service. The waste is considered as nuisance, and the health and economic costs of failing in managing solid wastes are rarely considered. For example in Moshi and Arusha towns, wastes from all sources are disposed off at the same dumping site.

It is therefore the aim of this paper first to look into the available methods of solid waste disposal in general and the existing practice in these towns. The second aim is to analyse water samples from nearby water sources for possible pollution and explain the mechanism of pollutant travel and effects of polluted water sources. Finally some proposals for the solid waste management in these towns will be given including some cost comparison for different available refuse collection systems.

2 CHARACTERISTICS OF SOLID WASTES

Categories of materials discarded in urban areas and generally viewed as a municipal responsibility to collect and dispose off include household garbage and rubbish, institutional refuse, construction and demolition debris, street cleaning and maintenance refuse, dead animals, catch basin and drain cleaning wastes, bulky wastes, abandoned vehicles and sanitation residue.

Industrial solid wastes require the attention of the municipality and fall within the municipal responsibility to manage in a manner that protects the public health and safety. Industrial wastes come from processing and non-processing industries, and therefore the composition is site specific. Small scale industrial enterprises generally discharge their wastes into the collection milieu of municipal refuse. Large scale industries are required to make their own hauling arrangements or pay a fee to the municipality for special service.

However most municipalities in developing countries apparently allow industrial wastes to be disposed within their fills without charging any fee to cover the cost of disposal. In the USA, for example, the industrial refuse is not treated as a part of municipal refuse. Its quantity is about three times that of municipal refuse and about 10 to 15 % is considered hazardous (Cointreau 1982).

Although there is no internationally accepted definition of hazardous wastes, legal definitious in use are generally based on technical criteria addressing short term acute hazards and long term environmental hazards e.g. toxicity, flammability, corrosivity, ignitability and reactivity. Although pathological wastes are hazardous to health, they have been customarily excluded from the definition (Helsing et al 1984).

The following tables show examples of the patterns of municipal refuse quantities and characteristics.

Table 1. Urban refuse generation rates (Cointreau 1982).

City or Country	Waste Generation Rate
Industrialized Countries:	
New York, New York, U.S.A	1.80 kg/cap/day
Hamburg, Germay	.85
Rome, Italy	.69
Middle-Income Countries	
Singapore	.87
Hong Kong	.85
Tunis, Tunisia	.56
Medellin, Colombia	.54
Kano, Nigeria	.46
Manila, Philippines	.50
Cairo, Egypt	.50
Low-Income Countries	
Jakarta, Indonesia	.60
Surabaya, Indonesia	.52
Bandung, Indonesia	.55
Lahore, Pakistan	.60
Karachi, Pakistan	.50
Calcutta, India	.51
Kanpur, India	.50

Note: For those cities in developing countries where the total refuse mix was subdivided into major categories of waste, data indicate that the residential portion of the total refuse was between 60 and 80%.

The cities shown in table 1 are large urban areas with more than one million residents. This means that the data is essentially applicable to big cities. There is no easy way to extrapolate the data so as to get the waste generation rate for small towns in developing countries. This is due to some site specific factors, and in large cities there is a higher commercial activity which results into higher waste generation rates. For the areas where an indication of service level must be estimated and data from the project preparation stage have not yet been developed, Cointreau (1982) suggested the following refuse generation rates:

residential refuse	0,3 to 0,6 kg/cap/day
commercial refuse	0,1 to 0,2 kg/cap/day
street sweepings	0,05 to 0,2 kg/cap/day
institutional refuse	0,05 to 0,2 kg/cap/day

If industrial solid wastes are included in the collection and disposal system, then 0,1 to 1 kg/cap/day may be added at the appropriate step in estimating the service delivery requirements (Cointreau 1982).

Most planners for the World Bank projects use a combined solid waste generation rate of 0,5 to 0,6 kg/cap/day (Cointreau 1982).

Table 2 shows the urban refuse densities for different countries arrayed according to income levels. The low densities in industrialized countries are due to higher percentage of non-putrescibles like paper and plastics which are often used for packaging of consumer goods. These materials have high void spaces and low moisture content.

In industrialized countries the density tends to be unchanged (Cointreau 1982). In middle and low income countries the refuse density changes from one step to another. For example in Tunis, Tunisia the refuse at the household was measured and it was 175 kg/m³, in the portable communal bins it was 200 kg/m³, in the curbside stationary containers it was 300 kg/m³ and in non-compacting trucks it was 400 kg/m³ (Cointreau 1982).

Table 3 shows the moisture content for different cities. The data show that the moisture content for refuse from cities of developing countries is higher than in industrialized countries. This is because the wastes from developing countries have a higher percentage of food waste in their overall refuse mix (Cointreau 1982).

Table 4 shows the composition of urban refuse for different cities which have been grouped according to income levels. The composition differs from city to another depending on the economic, cultural, climatic and geographical conditions of the particular city. Although the solid wastes are mixed together during the collection, there are differences in the composition depending on the source of the wastes. In tables 5 - 7 the variance of refuse composition by source of generation is shown.

Table 2. Urban refuse densities (Cointreau 1982).

Country	Waste Densities
Industrialized Countries:	
United States	100 kg/cubic meter
United Kingdom	150
Middle-Income Countries:	
Singapore	175
Tunisia	175
Nigeria	250
Egypt	330
Low-Income Countries:	
Thailand	250
Indonesia	250
Pakistan	500
India	500

Note: Most of the above data reflect waste densities at the source of generation, after placement in household containers or building containers. The high numbers shown for Pakistan and India are believed to reflect the density of refuse at the open collection points which predominate as part of the collection systems used in these two countries.

Table 3. Moisture content and vegetable/putrescible content (Cointreau 1982).

City or Country	Moisture Content	Vegetable/Putrescible Content
Industrialized country:		
Brooklyn, New York, U.S.A.	22%	22%
Middle-Income countries:		
Singapore	40%	5
Onitsha, Nigeria	45%	-
Manila, Philippines	60%	43
Low-Income countries:		
Bandung, Indonesia	80%	75
Calcutta, India	29%	36
Lahore, Pakistan	52%	49

Table 4. Urban refuse composition data (in percentage by weight) (Cointreau 1982).

Type of Material	Brooklyn, N.Y.	London, England	Rome, Italy	Singapore	Hong Kong	Medellin, Colombia	Lagos, Nigeria	Kano, Nigeria	Manila, Philippines	Jakarta, Indonesia	Lahore, Pakistan	Karachi, Pakistan	Lucknow, India	Calcutta, India
	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	-	7	<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.

Table 5. Variance of refuse composition by source of generation (Cointreau 1982).

Type of Material	Bandung, (76) Indonesia			Colombo, (77) Sri Lanka		
	Residential	Market	Commercial	Residential	Market	Commercial
Paper	10	8	12	8	8	28
Glass, ceramics	<1	<1	<1	6	< 1	8
Metals	2	< 1	1	1	< 1	1
Plastics	6	2	7	1	< 1	1
Leather, rubber	-	-	-	-	-	-
Textiles	4	< 1	3	1	1	1
Wood, bones, straw	< 1	< 1	1	1	0	2
Non-food total	22	11	24	18	10	41
Vegetative, putrescible	72	84	69	80	88	58
Miscellaneous inerts	6	5	7	1	2	1
Compostable total	78	89	76	81	90	59
TOTAL	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.

Table 6. Comparison and characteristics of refuse from three residential areas of Ibadan, Nigeria (Oluwande 1984).

Components	Mean % by Weight		
	G.R.A. (Govt Reserved Areas)	Private Layout Areas	Traditional Old Parts
Leaves	13.2	33.7	81.3
Paper	12.6	11.3	2.5
Garbage	65.3	41.6	8.2
Tin	4.6	6.2	3.5
Glass	2.1	2.5	0
Rag	1.6	3.4	4.3
Dust	0.6	1.3	0.2
Density	256 kg/m³	280 kg/m³	296 kg/m³
Moisture content	64.8%	61.4%	49.7%

Table 7. Comparison of refuse from two areas of a community in Ibadan, Nigeria (Oluwande 1984).

Components	Mean % by Weight	
	Local University Campus	Local People
Leaves	28 1	49.9
Paper	8.1	0.7
Garbage	43 2	4.4
Tin	3.7	0
Glass	4.3	0
Rag	2.0	0 5
Dust	10.6	44 5

Some wastes, particularly from industries are hazardous and require special consideration in collection and disposal. Table 8 shows a list of frequently encountered substances which are considered to be hazardous.

Table 8. List of toxic or dangerous substances and materials selected as requiring priority considerations (Helsing et al 1984, abstract from World Health Organization, Management of Hazardous Waste, European Series No. 14).

1. Arsenic and compounds
2. Mercury and compounds
3. Cadmium and compounds
4. Thalium and compounds
5. Berylium and compounds
6. Chromium (VI) compounds
7. Lead and compounds
8. Antimony and compounds
9. Phenolic compounds
10. Cyanide compounds
11. Isocyanites
12. Organohalogenated compounds excluding inert polymetric materials and other substances referred to in this list or covered by other derivatives concerning the disposal of toxic or dangerous wastes
13. Chlorinated solvents

Table 8. Cont'd.

14. Organic solvents
15. Biocides and phytopharmaceutical substances
16. Tarry materials from refining and residue from distilling
17. Pharmaceutical compounds
18. Peroxides, chlorates, perchlorates and azides
19. Esthers
20. Chemical laboratory materials, not identifiable and/or new with unknown effects on the environment
21. Asbestos
22. Selenium and compounds
23. Tellurium and compounds
24. Pollycyclic aromatic hydrocarbons (carcinogenic)
25. Metal carboryls
26. Soluble copper compounds
27. Acids and/or basic substances used in the surface treatment and finishing of metals

3 SOLID WASTE DISPOSAL METHODS

In analysing solid waste disposal methods the following must be considered (Zajic 1982):

- type of waste and generation rates,
- possible change in type of waste and in generation rate,
- locations available,
- costs,
- technical feasibility,
- flexibility,
- limitations,
- collection procedure,
- potential nuisance,
- public health,
- effect of local conditions,
- public opinion,
- weather.

Available methods are:

- open dumping and burning,
- composting,
- sanitary landfill,
- incineration,
- garbage grinding.

3.1 Open dumping and burning

In open dumping and burning method, refuse is generally spread over a wide area. The area is often a source of food and provides harbourage for rats and flies. The area becomes unhygienic and there will be odour and smoke nuisance. Open dumps are often a cause of water pollution. This has to be considered in trying to keep living areas reasonably safe.

Insect and rodent control is closely related to the problem of scrap heaps. The National Academy (1966) estimated that every 0,03 m^3 (one cubic foot) of garbage produces approximately 75000 flies. Although the refuse is not entirely composed of garbage, the fly attraction still exists.

3.2 Composting

3.2.1 Procedure in composting

Composting is an ancient science. It is used for converting putrescible plant and animal residue to more stable materials for use as fertilizers and soil conditioners. Although it is similar to sanitary landfill, microbial reactions are controlled to yield a more stable end product and at a faster rate. Both aerobic and anaerobic composting are possible. Anaerobic composting is slower and odouriferous.

If the composting process is to be maintained on an aerobic basis by relatively frequent turning for aeration, windrows or stacks on the surface of the ground appear to be more efficient than pits. If the decomposition is to be entirely anaerobic, or aerobic only during a short initial period, pits of about 1 m deep and varying in length and breadth in accordance with the daily quantity of raw material should be used (Rabbani et al 1983).

One of the major problems in composting is to separate the non-compostable material from the compostable material. The non-compostable materials are such as metal, rags, glass and tin cans. However, recent equipment developments have greatly improved the separation. Larger pieces of glass are manually picked up initially. Then, the pieces which cannot be picked up manually are pulverised to fine powder and retained with the compostable organics. This can be removed in the final stage of composting by using screens and air to blow off the fines. Light ferrous metallic objects, such as tin cans, are separated by means of electromagnets. Other salvageable materials, such as rags, are manually extracted. Plastics are also separated as most of them are non-biodegradable. Rags, scrap metal and some of the cardboard and bottles are sold for salvage (Zajic 1972).

The end product of composting is humus, whose chemical, physical and biological compositions vary because of differences in the nature the raw material used and the conditions of composting (Zajic 1972).

3.2.2 Types of composting

There are mainly two types of composting, namely open windrow system and mechanical system.

1) Open windrow system

In open windrow system, composting is done in the open air. Refuse is placed in piles of about 1,5 to 2 m high and about 2 to 2,5 m wide.

Aeration:	The refuse is turned periodically to ensure aeration and uniform composting.
Moisture:	The moisture content is adjusted to about 60 %. Excessive moisture as from rainfall is protected by covering the pile. If the pile is too dry a percolater is used to increase the moisture. Sprinkling can be used under extreme conditions of dryness.
Temperature:	After several days the heat will build up in the pile from microbial reactions. The temperature may go as high as 70 ^{o}C (Zajic 1972). The microbes change from mesophilic to thermophilic. As the compost gets stabilized, the temperature will fail to increase back to the 60 - 70 ^{o}C even if the heap is turned for aeration (Zajic 1972).

This open windrow system needs about 6 - 10 weeks for completion. In dry weather it may need only 2 - 3 weeks (Zajic 1972). For small operations the heap can be turned manually. For big operations there are special mobile machines for turning the heaps. Figure 1 shows a layout plan for a manually operated windrow compost plant (Nath 1984).

For composting refuse from small towns the Indore process can be used. In this process alternate layers of readily putrescible materials such as garbage and sewerage sludge and relatively stable matter such as straw, leaves and municipal refuse are stacked on open ground. The material is stacked to a height of 1,5 m. The material is turned twice during the composting period of six months. Due to low frequency of turning the material is aerobic only for a short period after piling and after each turn and is anaerobic for the rest of the composting period. The Bangalore process is a modification of this process.

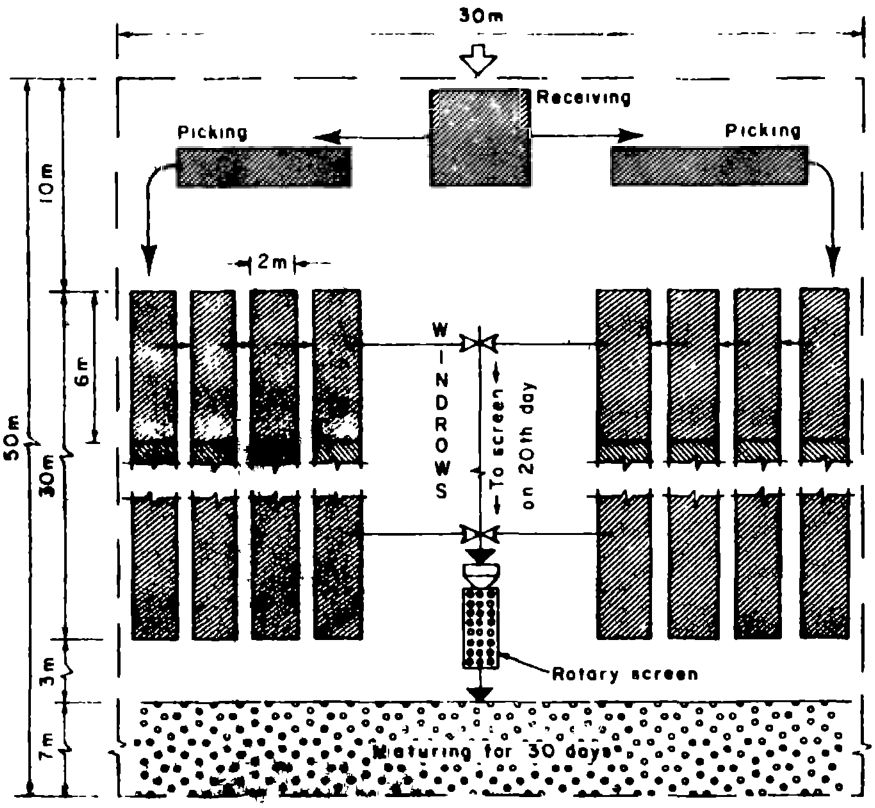


Figure 1. Layout plan for a manually operated windrow compost plant. Capacity: 10 tons refuse per day. Population: 20 000. Production: 5 tons of compost manure per day. Area: 1500 m². (Nath 1984).

2) Mechanical system

In mechanical system, a special chamber is constructed and it is fitted with mechanical devices to turn the compost continuously, adjust the moisture content, add air, inhibit the growth of harmful organisms and speed up composting process. The mechanical devices operate on the same principles as the windrow system. The main difference is that within 10 days a stable compost is produced. The contents of the special chamber are either mixed intermittently or continuously. In the intermittent mixing the special chambers are constructed vertically utilizing 4 to 6 floors, one above the other. These floors can be opened and closed once per day to transfer compost from one floor to the next lower floor. Therefore, the refuse wetted by sludge is elevated to the top of the tower. The material is retained on one floor for one day. This means that at the end of six days the compost will be at the lowest floor of the 6 floor tower. Then the compost is left as a unit for 2 or 3 days and the heat increases to 60 - 70 ^{o}C to destroy pathogens and seeds. The mass is then removed to the maturing sheds where it is transferred by an overhead grabing device from cell to cell until the process is completed. The continuous mixing system is carried out in chambers of cylindrical form that rotate, or in static systems equipped with ribbon screw conveyors, which act to stir the compost (Zajic 1972).

3.2.3 Factors affecting the rate of composting

Table 9 shows the factors affecting the rate of composting.

Table 9. Factors affecting the rate of composting (Gotaas 1956).

Factor	Comments
Particle size and structural strength of feedstock	Particle size should be small enough to give adequate surface area for microbial attack, but no so small that little void space remains between particles. Materials which lose their structural strength when wet should not be composted alone as the lack of void space would impede air movement. Optimum size is 1 - 4 cm for mechanical plants with forced aeration, or 4 - 8 cm for windrows and natural aeration.
Availability of nutrients	Nitrogen is the major nutrient required by the micro-organisms. An optimum ratio of carbon to nitrogen (C/N) is about 30 : 1. Municipal waste has a C/N about 60 : 1, so that nutrients need to be added, usually in the form of sewage sludge.
Moisture content	Water is required by micro-organisms, a minimum level of 30 per cent being necessary. The optimum level is the maximum achievable without filling the pore spaces with water and thus impeding air movement, and is usually about 50 - 60 per cent.
Aeration and agitation	Adequate aeration is necessary for the composting process. An optimum air flow of 2 - 6 m^3/day/kg of volatile solids is required during the thermophilic stage. Regular agitation aids aeration and exposes fresh material to attack, but too much agitation leads to excessive heat loss and compression of the heap.
pH control	pH changes from acid to alkaline during composting. However, deliberate pH control usually has little effect on the process.
Heap size	A minimum heap size is necessary, particularly in windrowing, to provide thermal insulation. The maximum size is determined by the prevention of overheating. Optimum size for windrows is about 1,5 m high and 2,5 m wide.

3.3 Sanitary landfill

This method of refuse disposal was developed in the 1930's as an alternative to the open dump. It has received acceptance by health authorities as the best method of land disposal. It is generally inexpensive and can handle wastes from nearly all normal sources (Salvato et al 1971).

Landfill is presently the most common method of municipal solid waste disposal. It was estimated in 1966 that 79 % of all cities in the USA with populations of over 25 000 people utilized landfills, with almost 81 % of the solid wastes disposed off in this manner (Baum et al 1974).

A sanitary landfill is defined as a precise method of disposing off refuse to land without creating a nuisance or public health hazard by utilizing principles of engineering to confine the refuse to the smallest practical area and to the smallest volume, and to cover it with a layer of earth at the conclusion of each day's operation, or more frequently if it is necessary (Zajic 1972).

The routine operations are:

a) Solid wastes are deposited in a controlled manner in a specially selected site.
b) Solid wastes are spread and compacted into thin layers.
c) Solid wastes are covered with earth daily or more frequently.
d) The cover material is compacted daily.

Because of the acceptance of this method, Moshi and Arusha towns are looking forward to have a similar utility in future if resources will allow, and it is therefore discussed more in detail.

3.3.1 Methods of sanitary landfill

Two general methods, an area method and a trench method, are used in sanitary landfill.

1) The area method

The area method is used when the terrain is unsuitable for excavation due to shallow groundwater or bedrock. Here, cover material needs to be imported.

The wastes are unloaded and spread in long, narrow strips on the land surface in a series of layers varying from 400 mm to 750 mm in depth. Each layer is compacted as the filling progresses during the day until the thickness of the compacted wastes reaches a height varying from 1,8 m to 3,0 m. At that time, and at the end of each day's operation, a 15 mm to 300 mm layer of cover material (earth) is placed over the completed fill (Tchobanoglous et al 1977). Figure 2 shows the area method of sanitary landfilling.

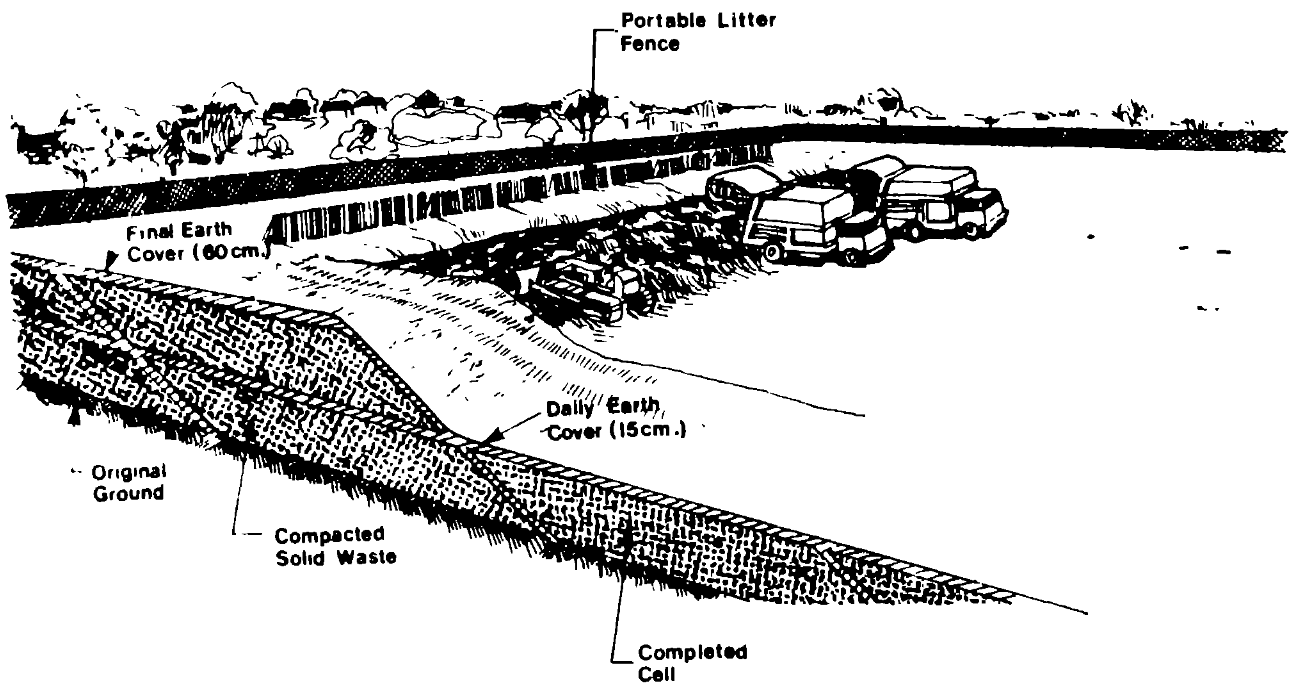


Figure 2. Area method of sanitary landfill (Leaning 1977).

2) The trench method

The trench method is suitable where adequate depth of cover material is available and the water table is not near the surface. The solid wastes are placed in trenches varying from 30 m to 120 m in length, 1 m to 6 m in depth depending on the groundwater level, and 5 m to 8 m in width (Tchobanoglous et al 1977).

To start the process, a portion of the trench is dug, the solid waste is piled to form an embankment behind the trench. The waste is then placed in the trench, spread into thin layers and compacted. Cover material is obtained by excavating an adjacent trench or continuing the trench that is being filled. Figure 3 shows the trench method of sanitary landfilling.

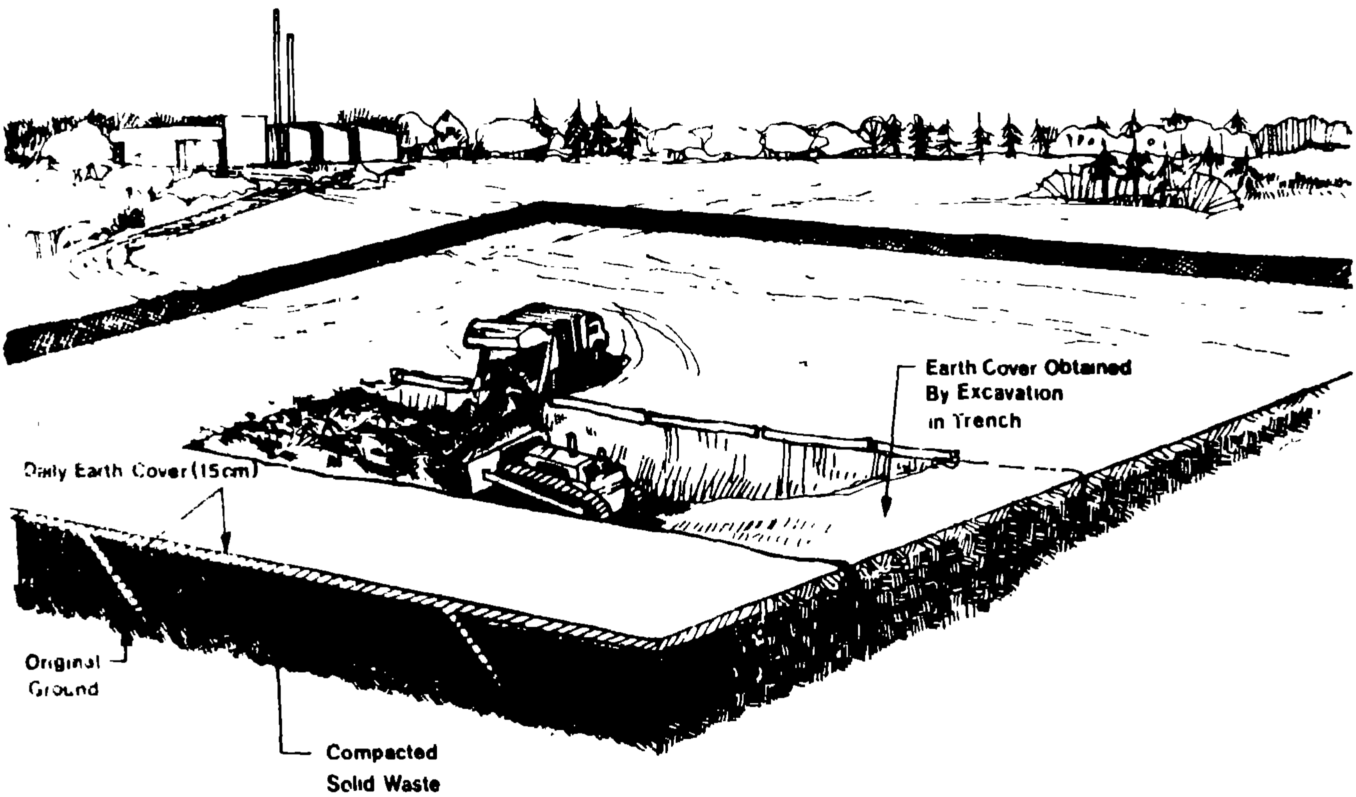


Figure 3. Trench method of sanitary landfill (Leaning 1977).

Figure 4 shows a possible combination of the two methods.

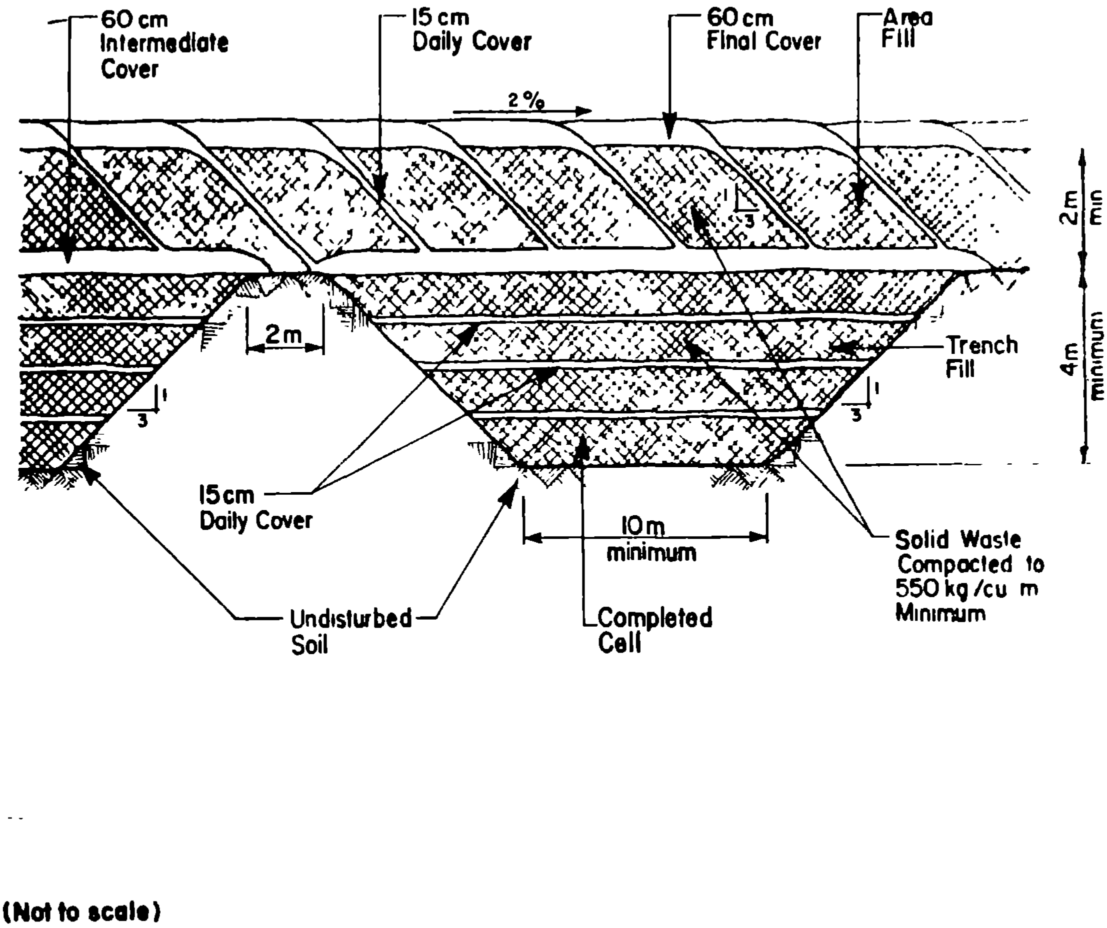
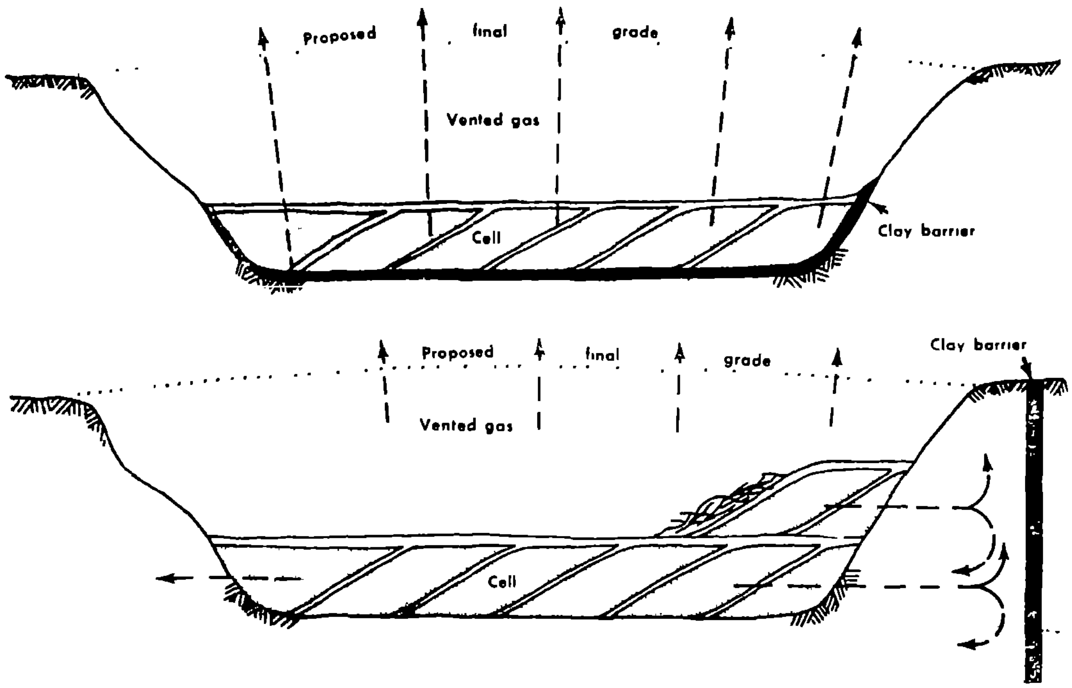
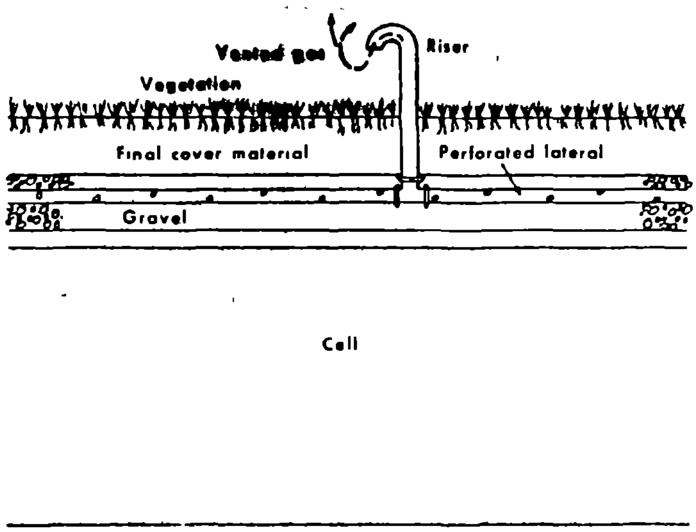


Figure 4. Cross sectional view for a combined trench area method of sanitary landfill (Leaning 1977).

Swamps and marshes, tidal areas and ponds, pits or quarries are typical areas that have been used as landfill sites. Due to possible contamination of groundwater by both leachate and gases from the landfill, the direct filling is no longer considered acceptable. Special provisions to contain the movement of the leachate and gases from completed fill have to be made. This can be accomplished by first draining the area and then lining the bottom with a clay liner or other appropriate sealants (Tchobanoglous et al 1977). Figure 5 shows clay placed as a liner in an excavation, clay installed as a curtain wall to block underground gas flow and method of gas venting.



a) Clay placed as a liner in an excavation and clay placed as a curtain wall to block underground gas flow.



b) Method of gas venting.

Figure 5. Control of gases from landfills (Wilson 1977).

3.3.2 Planning for a sanitary landfill

In planning a sanitary landfill, careful planning and design as well as good supervision and operation are needed to ensure sanitary and economical disposal. The factors to be considered are:

- knowledge of public health and nuisance of uncontrolled disposal,
- amount and type of wastes,
- standard operational procedures,
- capabilities of equipment to be used,
- topography and soil conditions,
- climatological conditions,
- land use and future land use,
- available land area and accessibility,
- surface and groundwater conditions (pollution hazards),
- relation to residences and industry,
- average haul distances for collection vehicles, and
- whether site will gain public acceptance.

In a typical sanitary landfill the following items are prohibited (Zajic 1972):

- explosives or highly combustible materials,
- car bodies,
- sheer iron and other scrap metals,
- tree stumps,
- corrosive or toxic materials,
- any materials constituting a hazard to safety of personnel or damage to equipment,
- carcasses of animals larger than a dog,
- waste building materials unless specifically permitted.

3.3.3 Design considerations for a landfill

The design for a landfill should describe the following:

- various facilities provided,
- how the site will be operated,
- the potential for pollution and its control,
- the planned use of the completed landfill,
- cost estimates for using the proposed site.

A topographical map showing the landfill site and about 300 m (1000 ft) of the surrounding area should be provided at different stages of the operation (start up, intermediate lifts and completed landfill).

A contour map sufficient to detail the operation should show the location of
- roads (on site and off site),
- fencing,
- drainage (natural and constructed),
- structures,
- scales,
- utilities,
- landfill areas,
- sequence of filling,
- borrow areas,
- fire protection facilities,
- gas control devices,
- leachate collection and treatment facilities,
- rainwater disposal area,
- entrance facility,
- land scaping,
- nearby water sources and structures.

Estimates including capital and operation costs should be made. Sources of funds, equipment costs, manpower requirement and costs, land costs and financing charges should be included in the final design report (Baum et al 1974).

3.3.4 Area requirements for a landfill

Baum et al (1974) reported the American Public Works Association Research Foundation's method for determining a required area for landfills.

The formula is

$$V = \frac{FR}{D} \left(1 - \frac{P}{100}\right) \qquad (1)$$

where V = landfill volume in cubic yards required for refuse disposal per capita per year

F = a factor incorporating the cover material, averaging 17 % for deep fills and 33 % for shallow fills with corresponding F values of 1,17 and 1,33

R = amount of refuse contributed in pounds per capita per year
D = average density of refuse in pounds per cubic yard delivered at the landfill
P = per cent reduction of refuse volume in the landfill, varying from 0 to 70 %

This formula is dimensionally homogenious and therefore the variables can be expressed as V in m^3, R in kg/cap/year and D in kg/m^3.

Figure 6 shows the probable land space required for sanitary landfilling of untreated wastes compared with space required for residues of treatment.

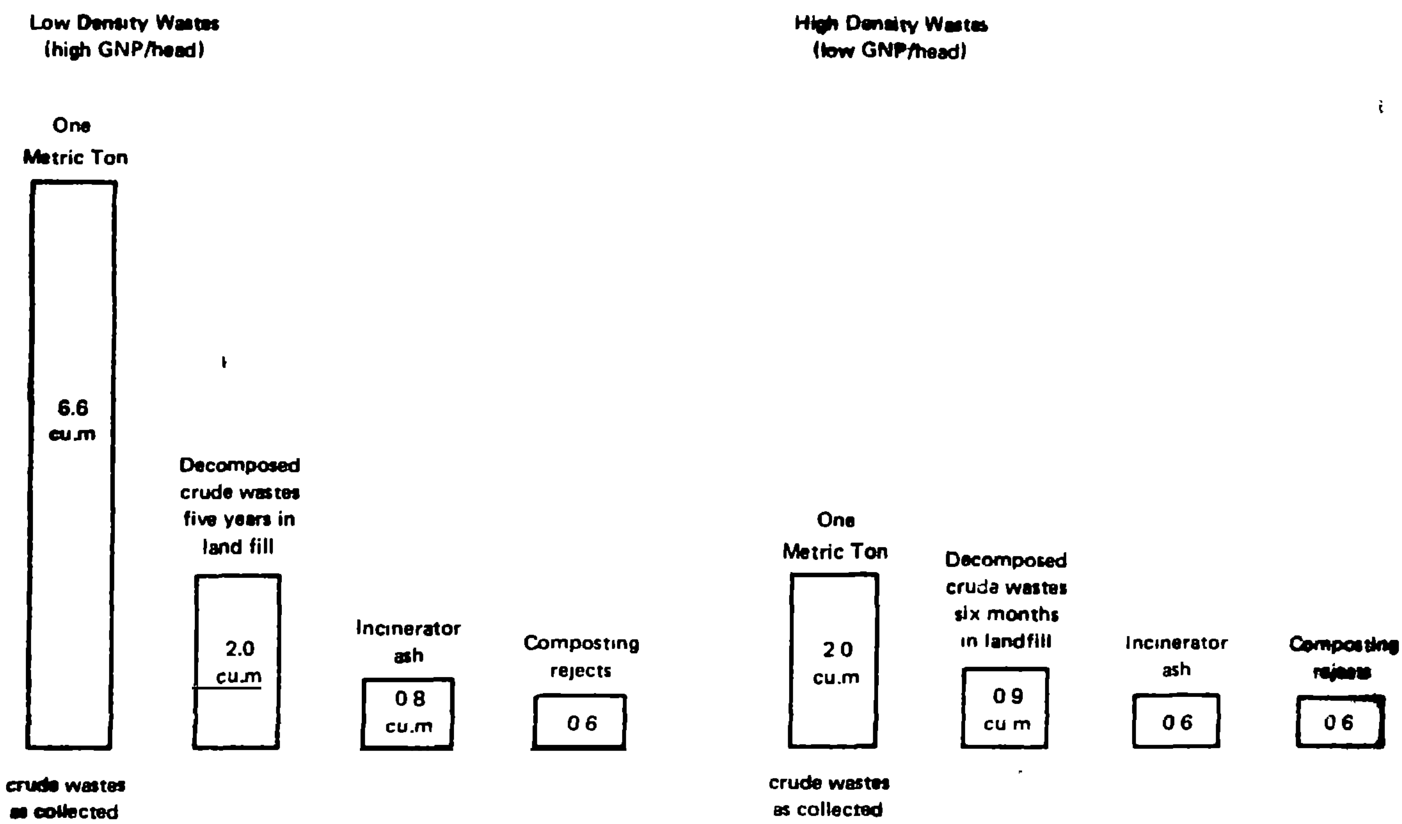


Figure 6. Probable land space required for sanitary landfilling of untreated wastes compared with space required for residues of treatment (Coitreau 1982).

3.3.5 Landfill equipment

The most common equipment is the crawler or rubber-tired tractor. It can be used with a dozer blade, trash blade or a front-end loader. A tractor is versatile and can perform the spreading, compacting, covering, trenching and even the hauling of the cover material. Depending on the existing situation, a rubber-tire or a crawler-type tractor and a dozer blade, trash blade or front-end loader can be selected. Scrapers, compactors, draglines, rippers and graders are other equipment normally used at large sanitary landfills.

Figures 7 and 8 show the standard landfill equipment and the specialized equipment. Table 10 shows the performance characteristics of equipment.

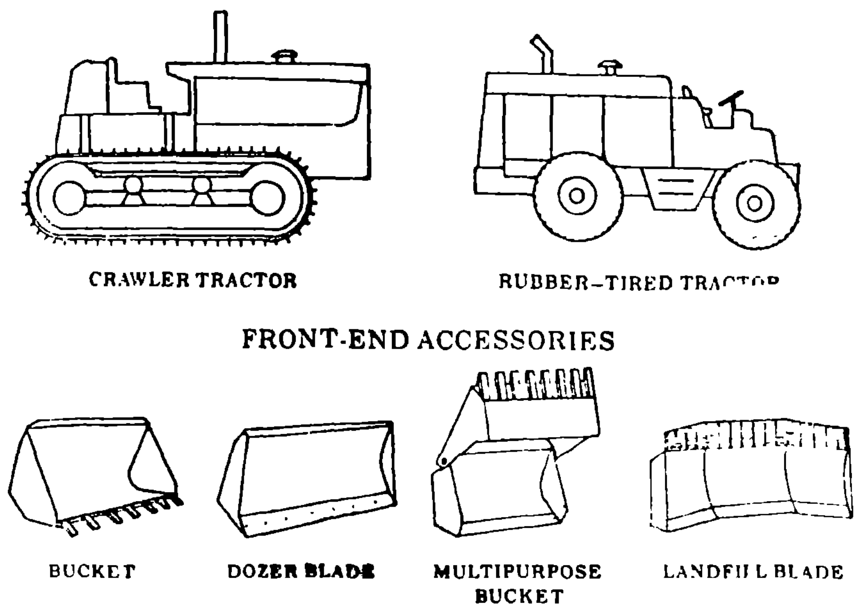


Figure 7. Standard landfill equipment (Baum et al 1974).

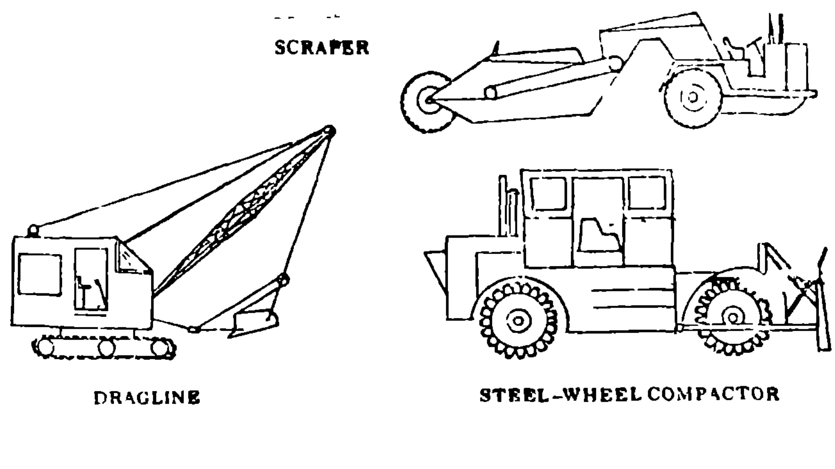


Figure 8. Landfill specialized equipment (Baum et al 1974).

Table 10. Performance characteristics of equipment (Baum et al 1974).

	Solid waste		Cover material			
Equipment	Spreading	Compacting	Excavating	Spreading	Compacting	Hauling
Crawler dozer	E	G	E	E	G	NA
Crawler loader	G	G	E	G	G	NA
Rubber-tired dozer	E	G	F	E	G	NA
Rubber-tired loader	G	G	F	G	G	NA
Landfill compactor	E	E	P	E	E	NA
Scraper	NA	NA	G	E	NA	E
Dragline	NA	NA	E	F	NA	NA

Basis of evaluation:

1. Easibly workable soil
2. Cover material haul distance greater than 1000 feet

Rating key:

E - Excellent
G - Good
F - Fair
P - Poor
NA - Not applicable

The size of equipment depends on the size of the operation. For landfill handling about 40 tons of solid wastes per day or less a tractor of 5 to 15 tons is sufficient. Heavier equipment is recommended for sites handling more than 40 tons per day. For a landfill handling about 115 tons per day or less one piece of equipment can manage. For these small sites with one piece of equipment, provision should be made for standby equipment. This can be arranged with other public agency or private concern for the use or rental of replacement equipment on a short notice in the case of a breakdown of the regular equipment. Larger sanitary landfills handling more than 260 tons per day require more than one piece of equipment. Specialized equipment can be used to increase the efficiency (Baum et al 1974).

3.4 Incineration

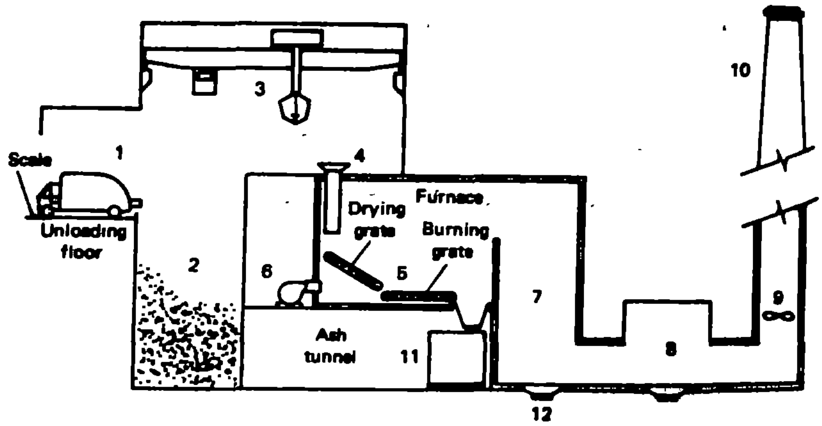
Incineration is a controlled combustion of waste to produce non-degradable residue and gaseous combustion products. The residue requires disposal and the gases require treatment, for example removal of entrained particles. Incineration becomes viable where land for surface tipping is not available within a reasonable distance and when wastes contain toxic substances.

Incineration requires high capital cost both for the incinerator and ancillaries including fans, lifting gear, instruments, pollution control and residue treatment. To support combustion continuously a secondary fuel, usually oil or gas is required throughout incineration. Provision for waste heat recovery involves extra capital cost and it is rarely justified (Bridgwater and Mumford 1979). However, at the Lakeview water pollution control plant in Ontario, Canada, a closed-loop thermal sludge conditioning and incineration system has been operating for over a year now. The system costed 29,4 million USD. The system does not require supplementary fuel, and engineers are re-assessing the economics of this disposal option (Anon 1985).

For better operation, lower costs and less air pollution, large municipal incinerators are preferred to small on-site incinerators. On-site incinerators are used in apartment houses, hospitals, schools, commercial and industrial establishments (Salvato 1982).

Basic operations in incineration of solid wastes are shown in figures 9 and 10.

The operation starts with the collection trucks (1) unloading solid wastes into the storage bin (2). The length of the unloading platform and storage bin depend on the number of trucks which must unload simultaneously. The depth and width of the storage bin depend on the rate at which waste loads are received, and the rate of burning. The overhead crane (3) is used to batch waste into the charging hopper (4). The crane operator can select a mix to achieve an even moisture content in the charge. Large incombustible wastes can also be removed. From the hopper solid wastes fall into the stokers (5) where they are mass-fired. Air may be introduced from the bottom of the grates by a forced draft fan (6) or above the grates to control the burning rate and furnace temperature. The heated air rises over the incoming high moisture wastes at the top of the drying grate and drives off the moisture to permit burning as the wastes travel down to the grate. Because organic wastes are thermally unstable, various gases are driven off in the combustion process taking place in furnace where the temperature is about 760 ^{o}C (1400 ^{o}F). These gases and small organic particles pass into the secondary chamber normally called the "combustion chamber" (7) and burn at temperature in excess of 870 ^{o}C (1600 ^{o}F). Odour producing compounds are usually destroyed at this temperature range (Tchobanoglous et al 1977).



1. Collection truck
2. Storage bin
3. Overhead crane
4. Charging hopper
5. Travelling grate stokers
6. Forced draft fan
7. Combustion chamber
8. Gas cleaning equipment
9. Induced draft fan
10. Stack
11. Residue hopper
12. Flyash sluiceway

Figure 9. Section through a typical continuous-feed mass-fired municipal incinerator (Tchobanoglous et al 1977).

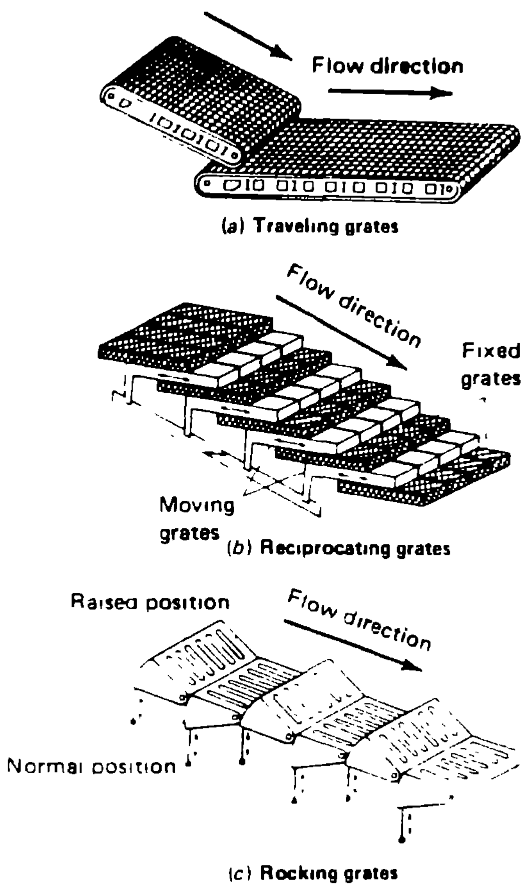


Figure 10. Typical stokers used in mass-fired incinerators (Tchobanoglous et al 1977).

Flyash and other particles may be carried through the combustion chamber, and therefore space must be provided for air-cleaning equipment (8) to meet local air pollution control regulations.

To supply air to the incinerator as well as to secure adequate air flow to provide for head losses through the air-cleaning equipment, an induced-draft fan (9) may be needed. Cleaned gases are discharged to the stack (10) as end products of incineration. Unburned materials and ashes from the grates fall into a residue hopper (11) located below the grates where they are quenched with water. Flyash that settles in the combustion chamber is removed by the flyash sluiceway (12).

Residue from the storage hopper can be taken to a sanitary landfill or to a resource recovery plant. Wastes from the air-cleaning equipment and flyash from the sluiceway can be taken to a sanitary landfill. Therefore the three essentials for combustion are (Salvato 1982):

1) There must be enough time to drive out the moisture.
2) Temperature must be raised to ignition point. For the combustion of unburned furnace gases, elimination of odours and combustion of carbon suspended in the gases, the temperature range of 760 ^{o}C (1400 ^{o}F) to 870 ^{o}C (1600 ^{o}F) is necessary.
3) Turbulence is necessary to ensure mixing of gases formed with air to completely burn the volatile compustible matter and suspended particulates.

3.5 Garbage grinding

Grinding is one alternative for garbage disposal. There are two systems for garbage grinding:

1) The home grinder is connected to the kitchen sink drain. Garbage is shredded into small particles while being mixed with water and discharged to the house sewer.
2) The garbage is collected and dumped into large centrally located garbage-grinding stations that discharge garbage to the municipal sewage system. With garbage grinding, the volume of solid waste could be decreased by 10 %. It also significantly reduces the populations of flies and rodents (Zajic 1972).

3.6 Cost aspects of solid waste disposal

Cost data from developing countries is very limited. This is due to scarce resources, and therefore the field is nto well developed. To show the trend of costs, data from some industrialized countries and some Asian countries is used. Figure 11 shows an example of sanitary landfill costs in the USA.

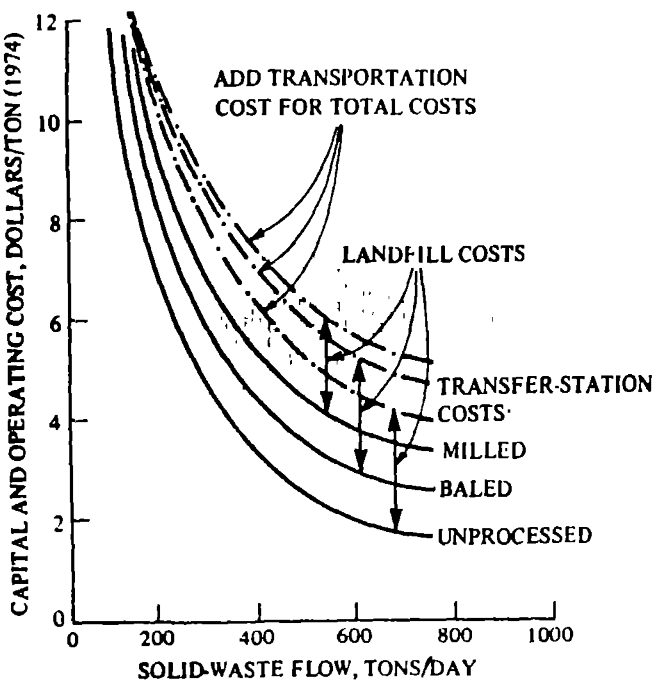


Figure 11. An example of landfill costs (Wilson 1977).

Figure 12 shows the effect of size on estimated sanitary landfill costs in the USA (costs in USD in 1969 price level).

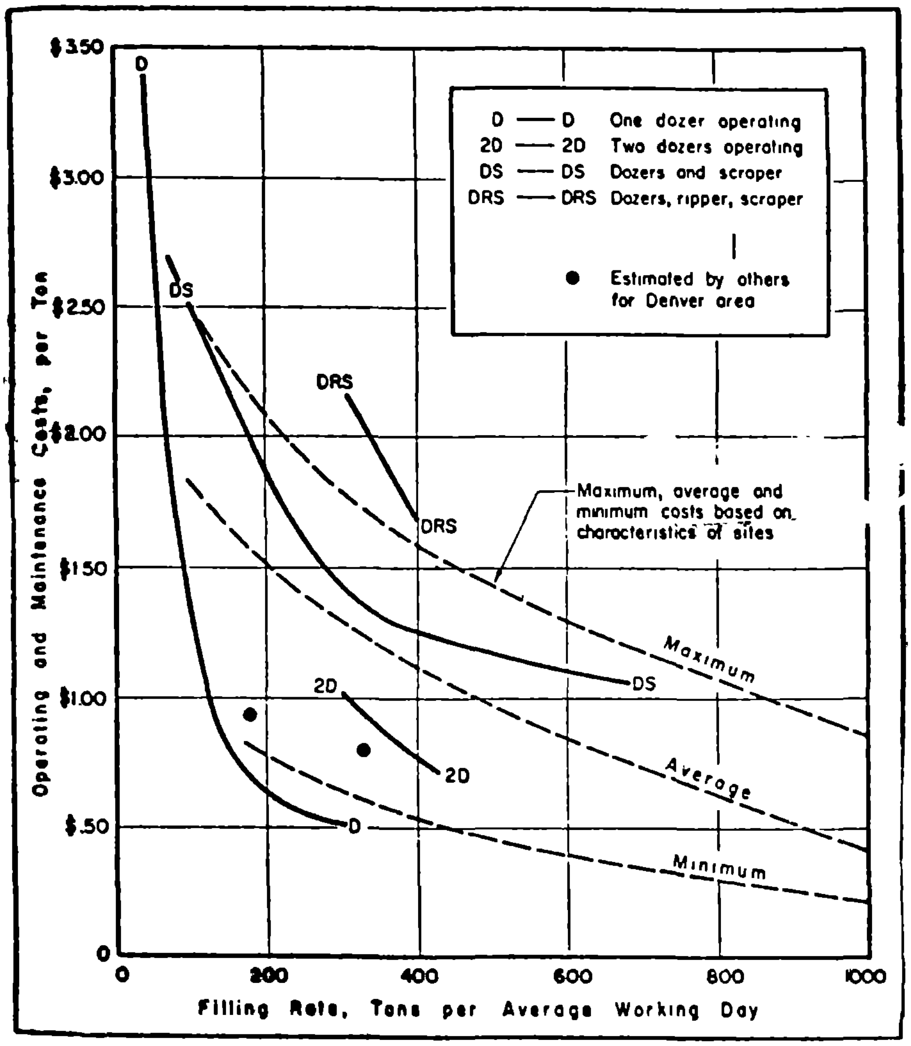


Figure 12. Effect of size on estimated sanitary landfill costs (Wilson 1977).

It can be stated from figures 11 and 12 that as the size of the sanitary landfill gets smaller, the capital, operating and maintenance cost gets higher per a ton of solid waste disposed. This is mainly attributed by the proportions of fixed and variable costs.

To compare the costs of a sanitary landfill with other methods of solid waste disposal, table 11 shows the costs of handling and disposing off municipal solid waste for an urban area in the Middle East, and figure 13 shows the costs for alternative methods of disposal in India.

Table 11. Estimated costs of handling and disposing of municipal solid wastes for an urban area in the Middle East, via three alternative methods (GBP in 1979 price level) (Betts 1984).

	Transfer and Bulk Haul to Landfill (2 station)		Incineration with Energy Recovery		
	Without Static Compaction	With Static Compaction	Option A (Electricity production)	Option B (Heat for direct use)	Composting
Total capital cost £'000	5,100†	5,340†	30,000–34,500	28,500–32,250	12,750–20,250
Total annual operating cost, £, when capital amortized. @ 5%	813,996	780,048‡	3,300,000–3,615,000	3,105,000–3,375,000	1,680,000–2,565,000
@ 10%	1,002,703	978,477‡	4,470,000–4,965,000	4,215,000–4,635,000	2,160,000–3,330,000
Revenue from sale of recovered products, £ per annum	--	—	525,000–1,110,000	60,000–210,000	60,000
Net saving on disposal costs, £ per annum	(– 165,000)§	(– 165,000)§	600,000–900,000	600,000–900,000	705,000
Net cost £ per tonne of waste for handling and disposal when capital amortized: @ 5%	3.56	3.44	4.70–9.06	7.26–9.87	3.33–6.54
@ 10%	4.25	4.16	8.94–13.97	11.30–14.46	5.07–9.33

*All options are based on annual quantity of waste for handling/disposal of 275,000 t (projected arisings by 1984/85)
†For transfer stations, bulk haul vehicles, and associated equipment only
‡Assumes that a compaction ratio of 1 1.50 is consistently achieved
§Cost of landfill site operation, calculated at £0.60/t, including capital amortization. This figure is added to the operating costs for transfer and bulk haul, to give the net cost per tonne of waste for handling disposal via a transfer system

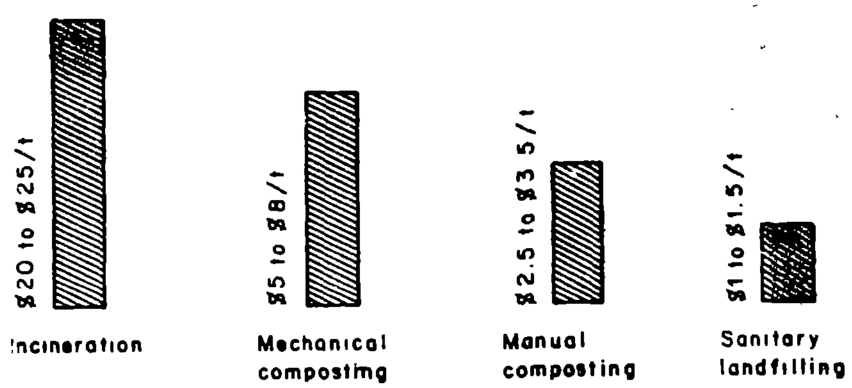


Figure 13. Costs for alternative methods of solid waste disposal in India (Nath 1984).

It can also be stated from table 11 and figure 13 that sanitary landfilling is the cheapest option, followed by manual composting. Nath (1984) reported the economic status and the relative cost effectiveness of different methods of composting in India, and results are shown in tables 12 and 13. Costs are in Indian rupees per a ton of refuse.

Table 12. Technical and economic status of some Indian compost plants (Nath 1984).

			Calcutta	Delhi	Bangalore	Baroda
1.	Name of Municipal Corporation					
2	Quantity of refuse generated (tonnes/day)		1,800 to 2,000	1,600 to 1,800	1,000 to 1,100	
3.	Design input capacity (tonnes/day)		125	150	200	150
4	Year of commissioning		1978	1980	1978	1979
5.	Quantity of compost produced (tonnes/day)		60	70	100	75
6.	Composting system used		Pre-treatment	Pre-treatment	Pre-treatment	Pre-treatment
7.	Average chemical analysis of compost produced	N	0.52	0.96	—	0 70
		P_2O_5	0.70	0.51	—	0.90
		K_2O	0.66	0.87	—	0.90
		C/N	20 00	17 00	—	18.00
8.	Cost per ton of finished compost (R /tonne)		66.00	80.00	82 00	90 00
9	Sale price of compost (Rs./tonne)		40.00	40.00	50.00	50 00
10	Revenue from sale of rejects		Nil	Nil	Nil	Nil
11	Loss per tonne of compost (Rs /tonne)		26 00	40 00	32 00	40.00
12	Cost of disposal of refuse (Rs /tonne)		13.00	20 00	16 00	20.00

Table 13. Relative cost effectiveness of different methods of composting in India (Nath 1984).

Method of Composting	Capacity (t/day)	Production Cost (Rs /t)	Sale Price (Rs /t)	Remarks
1 Indore/Bangalore method (manual)	1–20	1–30	1–35	36% of the plants are self-paying
2. Windrow composting post-treatment (manual)	3–5	30–40	30	
3 post treatment (manual)	10–20	20–30	30	Self-paying
4 post-treatment (manual)	50	40	30	
5. Post-treatment (semi-mechanical)	200	50	40–50	Could be self-paying
6. Pre-treatment (mechanical --- Western type)	200	90	40–50	Would not be self-paying

4 THE EXISTING PRACTICE OF SOLID WASTE DISPOSAL IN MOSHI AND ARUSHA TOWNS

4.1 The study area

4.1.1 Moshi town

1) Location and topography

Moshi town is located at latitude 03^{o}21' S and longitude 37^{o}20' E in the United Republic of Tanzania. It is on the southern slopes of Mount Kilimanjaro. The area generally slopes from north to south with gradients progressively decreasing from 1 : 20 to 1 : 100. Rivers originating from the mountain run generally from north to south. River Karanga flows on the west of the town forming a part of the western boundary of the town, while the eastern edge of the town centre is bounded by the Njoro stream originating from a spring within the town (appendix 1).

2) Climate

There is one rainy season from October to May. The mean annual rainfall (63 years) is 930 mm out of which 630 mm or approximately 67 % fall between March and May. Below is shown a mean monthly rainfall calculated over 63 years in millimetres per month from the Moshi Meteorological Station (No. 93 3700 4) of the East African Meteorological Department, and available in the Regional Water Engineer's office.

Table 14. Mean monthly rainfall in Moshi Meteorological Station for 63 years.

Month	Average monthly rainfall (mm/month)	Standard deviation	Coefficient of variation
October	31,6		
November	57,8	60,4	105
December	51,2	50,2	96
January	37,4	42,9	115
February	44,7	40,4	90
March	116,8	95,6	82
April	316,8	188,6	60
May	197,7	118,5	61
June	33,0		
July	14,3		
August	15,2		
September	14,6		
Total	931,6		

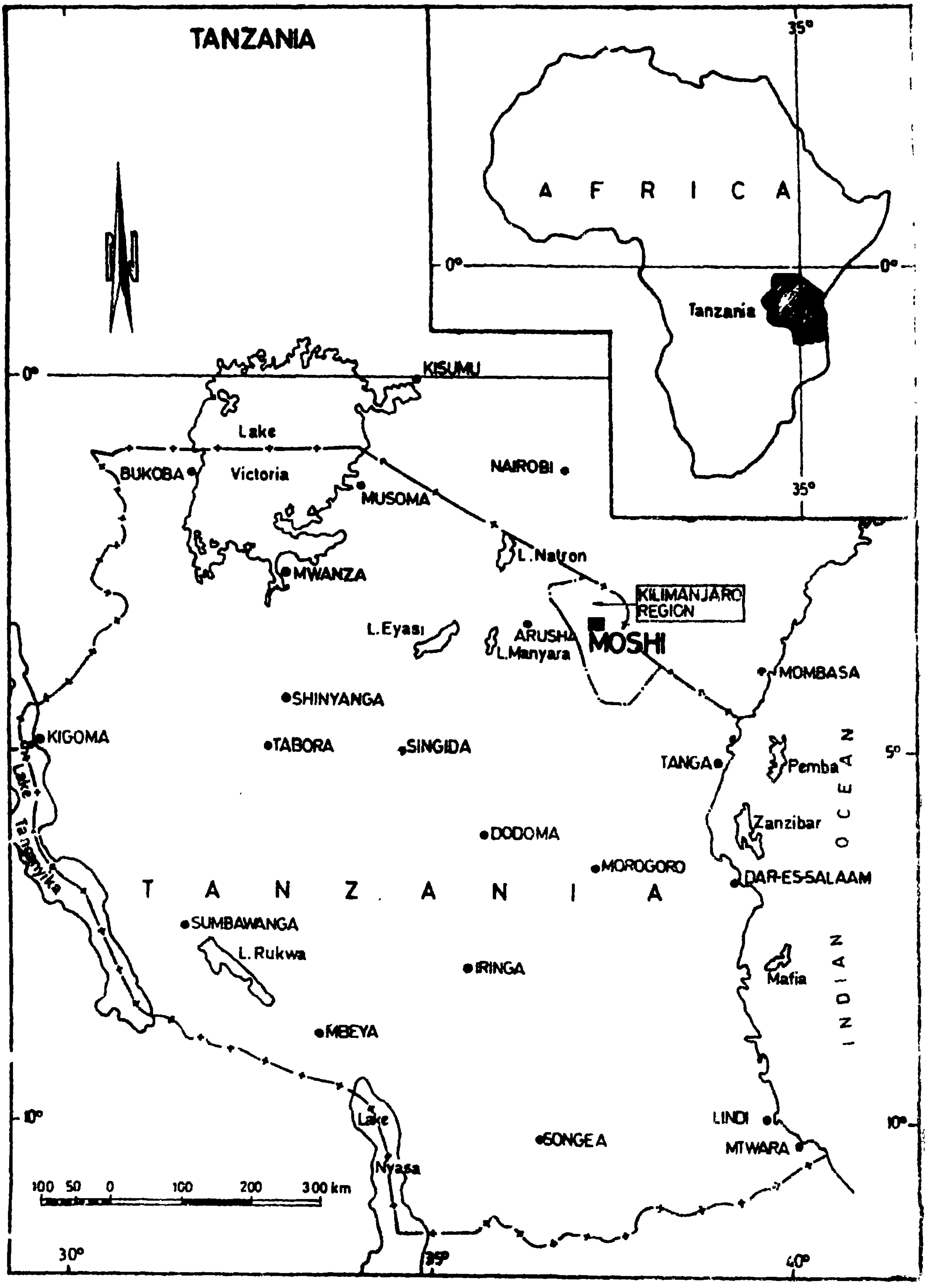


Figure 14. Moshi and Arusha in Tanzania (Gauff 1981).

The maximum mean monthly temperature recorded is 33,2 °C which occurred in February, while the minimum mean monthly temperature recorded is 15,5 °C which occurred in August. The average temperature for August is approximately 20 °C and the maximum mean temperature for the same month is 26,5 °C.

Monthly evaporation varies from 234 mm to 294 mm in September - March and from 128 to 135 mm in May - July (Gauff 1981).

3) Geology and soils

Moshi town is built on unmetamorphosed alkaline volcanic rock of the meocene period, overlain by recent ferrogenous tropical soils. Rock levels vary 1,0 - 1,5 m below the ground level from Moshi north to Moshi south. A "murram" type of soil immediately overlay the volcanic rock in varying thicknesses of 0,3 - 0,6 m. Volcanic rock entcrops in some parts of the town. However, generally the rock is fissured and pickable down to 6 m or more, except in some areas where the readily pickable depth is sometimes limited to 3 m (Gauff 1981).

4) Population

Population census was carried out in 1967 and 1978. The gross urban area population was 26 864 inhabitants according to the 1967 census and 52 223 inhabitants according to the 1978 census. The annual growth rate of the population within the urban area was assessed to be 4,8 % from 1967 to 1978. The results of the census and the assessed growth rate are not immediately comparable. This is because some organizational changes and several changes in the township boundary were made. The following annual growth rates were approved by the Ministry of Lands, Housing and Urban Development.

1978 - 1991	5,5 %
1992 - 2004	4,5 %

Table 15. Population projections in Moshi Master Plan area (Hankkio and Berege 1974).

YEAR	HIGH ESTIMATE		TARGET ESTIMATE		LOW ESTIMATE	
	NUMBER	G.R.%	NUMBER	G.R.%	NUMBER	G.R.%
1973	61 000		61 000		61 000	
1979	95 000	7•7	87000	6•0	83000	5•2
1984	140000	8•2	118000	6•4	109000	5•5
1989	207000	8•2	160000	6•4	142000	5•5
1994	309000	8•2	210000	5•5	186000	5•5

Although the above growth rates were approved, the population figures resulting from projections using the above growth rates are higher than the true population. This can be seen from the population census of 1978. As a result of this, Gauff (1981) proposed another projection and it is shown in figure 15.

4.1.2 Arusha town

1) Location and topography

Arusha town is located at latitude 03^{o}22' S and longitude 36^{o}40' E in the United Republic of Tanzania. It lies on the southern slopes of Mount Meru. It falls from an elevation of about 1450 m above sea level in the north to a present level of 1300 m in the south. The area is intersected by a number of streams, all of them flowing north-south. The Themi stream and the Naururu stream pass through the town centre, while the Bunka river effectively forms the western boundary of the town and the Kijenge river forms the eastern boundary (appendix 2).

2) Climate

The climate for Arusha town is summarised in table 15.

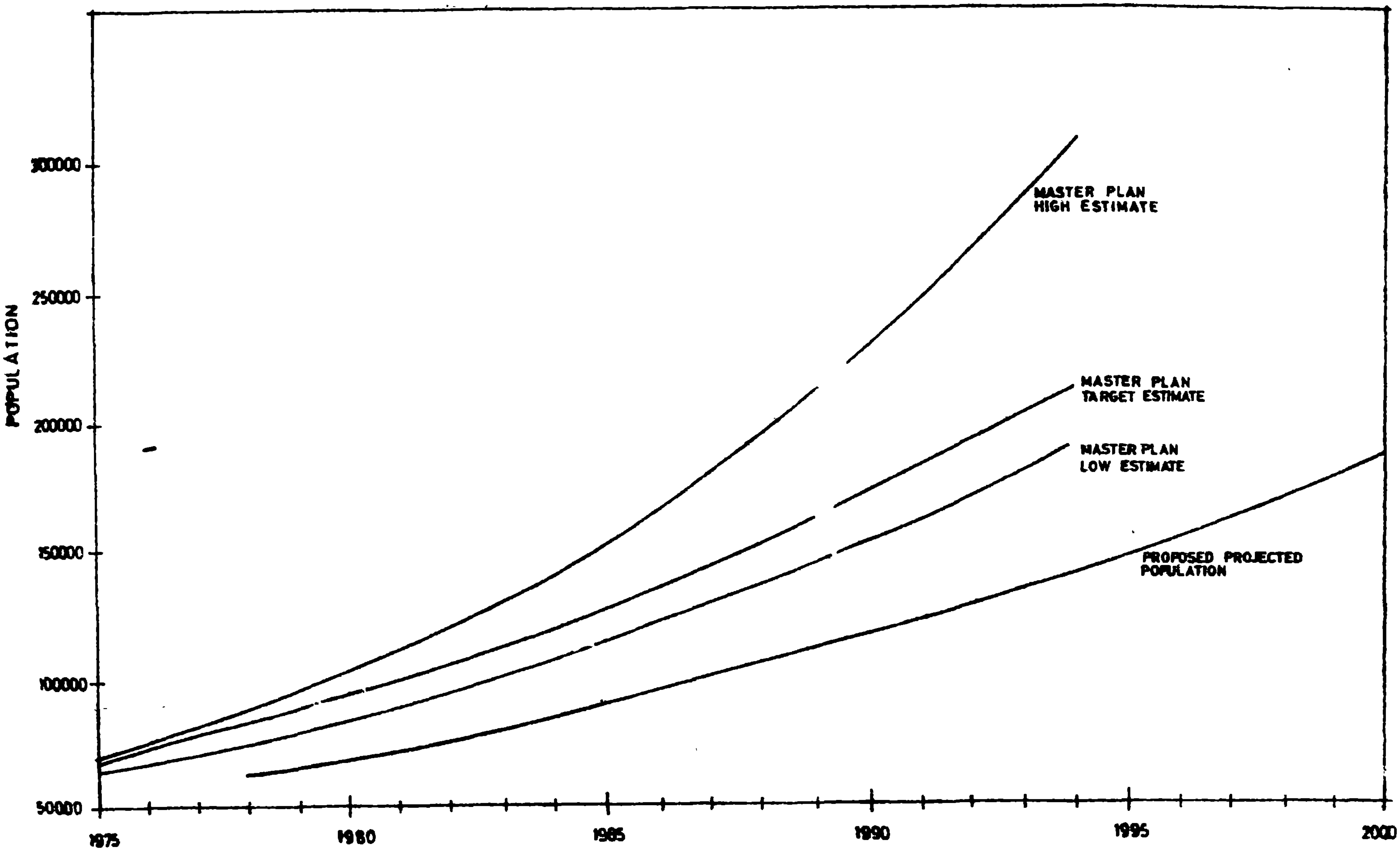


Figure 15. Moshi population projections (Gauff 1981).

Table 16. Climatic data for Arusha town, based on Arusha Airport Meteorological Station No. 93, 36/033 (Gauff 1980).

Month	Temperature in 1960 - 78 (°C)				Rainfall (mm) 1960 - 70					
	extreme max	mean max	mean min	monthly mean	monthly mean	mean	highest	lowest	24 hours max	monthly evaporation (mm) 1971 - 78
January	32,2	28,0	13,3	8,3	71	71	172	1	43,7	174
February	33,5	28,4	13,8	9,0	86	88	225	14	82,4	174
March	33,3	27,5	15,1	9,7	137	145	256	47	54,4	167
April	31,2	25,0	16,0	10,5	233	249	456	39	116,8	108
May	27,6	23,2	13,0	9,8	69	66	152	3	24,9	96
June	27,1	22,0	12,9	5,3	23	18	67	1	39,9	108
July	26,5	21,7	12,3	4,8	9	11	40	0	21,3	130
August	29,3	22,9	12,3	5,0	6	7	45	0	16,6	152
September	29,5	25,1	12,6	6,7	10	10	59	0	22,2	171
October	32,6	27,0	13,8	4,0	23	25	124	1	27,4	254
November	31,4	27,1	14,6	9,2	94	139	462	1	148,8	210
December	33,4	28,8	13,9	9,0	83	98	260	16	94,3	130
	33,5	25,6	13,8	4,0	844	927	1543	514	148,8	1874

3) Geology and soils

Mount Meru is the dominant geologic feature of the area. It is a dormant volcano of the Vesuvian type, with its cone made up of basalts, basaltic ashes and tuffs. During the period of its formation, much of the debris was washed down the slopes as mud flows. This formed the low gradient apron around the base of the mountain, on which Arusha town is built (Gauff 1980). The parent materials for the soils in Arusha town are predominantly lavas and ashes that have decomposed into clays that exhibit the features of soils that shrink and swell. These clays are interspersed with loams containing river worn gravels, rocks and small boulders. The northern part of the town including the town centre generally consists of loamy soils overlaying silty clays and gravel and boulder beds of depths varying from 3 to 7 m. The area exhibits generally high infiltration rate with good sub-surface drainage (Gauff 1980).

The southern part of the town has localised thin loamy top soil overlaying silty clays and clays. Areas of black cotton soils occur and become extensive to the southwest. This area exhibits a varying permeability being high at the end of the dry season and then becoming rapidly effectively impermeable as the rainy season proceeds. Surface water run-off and gullying occur particularly in April and May (Gauff 1980).

4) Population

The population census for the past years is as shown in table 17.

Table 17. Population data for Arusha town (Gauff 1985).

Year of census	Urban population	Growth rate (%)
1957	10 000	
1967	32 452	12,0
1978	55 281	5,4

The Arusha Municipal Council and the Ministry of Water, Energy and Minerals agreed the growth rate to be 5,7 % for 1978 - 1980 and 6 % for 1981 - 1990 per year (Gauff 1985). Also Gauff (1985) proposed the population to be as shown in table 18.

Table 18. Proposed population for Arusha town (Gauff 1985). The growth rate has been worked out from the data given.

Year	Urban population	Growth rate (%)
1978	55 281	6,0
1980	62 189	6,0
1990	111 371	6,0
2000	199 449	6,0

Based on the growth rate of 6 %, the population of Arusha town in 1985 is about 83 000 inhabitants. Also Leaning (1977) prepared Utilities Masterplan for Arusha District for the years 1977 - 1997. He projected and summarised the population as shown in figure 16.

4.2 Generation rates

4.2.1 Moshi town

The Moshi town council data indicate a total production of solid wastes as follows:

1982	20 000 tons (55 tons/day)
1983	32 400 tons (87 tons/day)
1984	32 480 tons (87 tons/day)

The figures include wastes from households, commercial areas, institutions, industries, construction and demolition debris including street sweepings.

A survey was conducted on the generation rate and for one week. There was a total of 48 trips for side loading non-compacting trucks of 12 m^3 capacity and 12 trips of tractor trailers from the market.

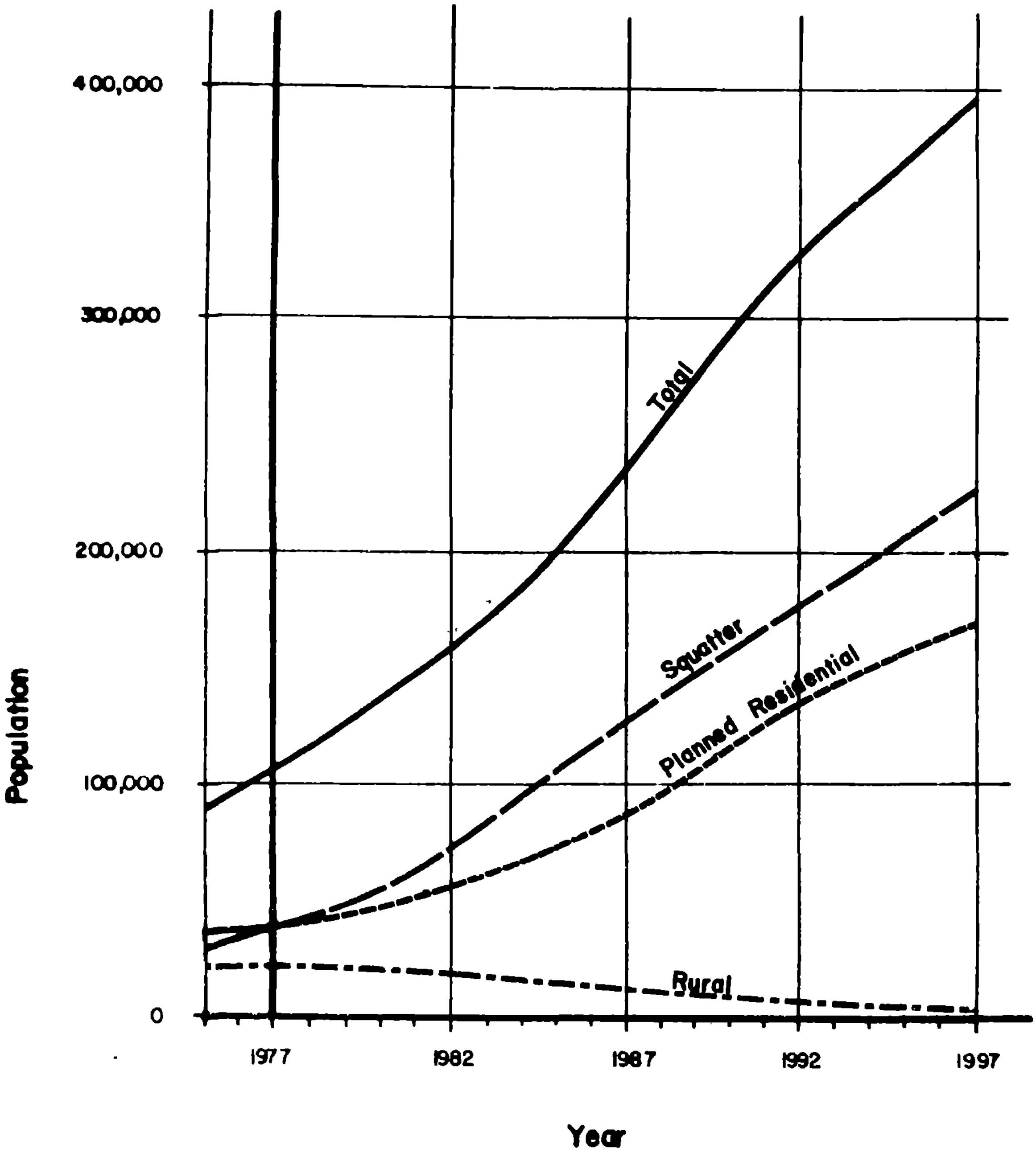


Figure 16. Projected population growth in Arusha town (Leaning 1977).

The trucks are about 80 % of full capacity and the trailers carry about 5 m^3. This gives a total volume of about 520 m^3 per week. The average daily volume collected is therefore 74 m^3. Various samples were weighted on site and the average density was 330 kg/m^3. Therefore the total weight collected per day is about 24,6 tons. The areas serviced included areas 1, 2, 3, 5, 6, 11, 12, 13 and half of areas 4, 10, 9 and 15 of the masterplan areas shown in appendix 3.

These areas had a population of 34 725 people in the 1978 census. This gives approximately 50 500 people in 1985 for a growth rate of 5,5 % in a period of 7 years, resulting to a total production rate of 0,49 kg/cap/day. This is the production rate of solid wastes as collected and not as produced.

Table 19. Random weight of samples and density of refuse.

Sample No.	Weight (kg)	Volume (m^3)	Density (kg/m^3)
1	8,6	0,02	430
2	5,5	0,02	275
3	6,8	0,02	340
4	5,5	0,02	275
5	5,0	0,02	250
6	4,1	0,02	206
7	10,0	0,02	500
8	6,4	0,02	320
9	3,6	0,02	180
10	10,0	0,02	500
Average	6,6	0,02	330

Compacting the refuse increased the density of the refuse by 20 - 45 % making the use of compacting trucks unnecessary. Moisture content is more than 50 % because sun-dried refuse at the dumping site weighted less than 50 % of the wet weight of refuse from the same source (particularly wastes from the market areas).

The bulk of the refuse is organic in nature. The composition by weight is shown in table 20.

Table 20. Composition of refuse (percentage by wet weight basis).

Item	Composition (%)
Vegetable/putrescible	81
Glass	3
Paper	2
Metal	2
Plastics	1
Leather	1
Wood, bones	3
Textiles	2
Miscellaneous inerts (stones, brick particles)	5
Total	100

In Moshi there is a wastewater treatment plant for the 16 % of the town which is sewered. Wastewater from soakage pits which are emptied after they are filled is transported by soakage pit emptiers to a collection chamber which is located at about 0,5 km from the treatment plant and joins the main sewer to the treatment plant. When working, the sewage sludge from drying beds is directly sold as fertilizer to residents, and there has never been excess.

4.2.2 Arusha town

Data obtained from the Arusha Municipal Council claim a total production rate of 130 tons per day. As it is the case for Moshi town, this includes wastes from all sources. The population of the town was 55 281 inhabitants in the 1978 census, and the projected present population is about 83 000 inhabitants.

In Arusha, a one week survey on the refuse collected was as follows:

- 12 trips by a truck with the capacity of 12 m³,
- 13 trips by a truck with the capacity of 8 m³,
- 13 trips by a tractor and a trailer with the capacity of 5 m³.

The 12 m^3 trucks are 7 ton vehicles with a covered platform and carry about 80 % of the full capacity. The 8 m^3 trucks are 10 ton vehicles but with an open platform. The trailers carry about 5 m^3 only. This gives a total volume of 420 m^3 per week or 60 m^3 per day.

Leaning (1977) evaluated the density of the refuse in Arusha town and it was 275 kg/m^3. Based on this density, the amount of refuse collected per day is 16,5 tons. The area serviced has a population of about 46 000 people in 1985. This gives a generation rate of 0,36 kg/cap/day. Table 21 shows a survey of solid waste collection in Arusha done by Leaning (1977). The average weight of refuse collected per day was 10,2 tons and the generation rate was 0,33 kg/cap/day. This means that there has been an increase in the generation rate. This can be due to increased consumption as well as the improved level of service.

The refuse collected does not include the following:
- most of squatter areas,
- litter, road side dumping and burning,
- other private dumping and disposal like composting and burning,
- light and heavy industries.

The generation rate obtained for Moshi town is higher than that for Arusha municipality. This can be due to higher commercial activities in Moshi town. On the other hand this can be attributed by the existing condition which has very much affected the level of service (e.g. lack of fuel for the collection trucks).

During the same time Leaning projected the total generation rate for Arusha District which includes all areas and is shown in figure 17. This was on the basis that the generation rate would increase by 7 % up to 1982 and by 4 % from 1982 to 1997.

Leaning (1977) also estimated the generation rate to be 0,5 kg/cap/day for the serviced areas and 0,26 kg/cap/day for the squattered areas in 1982 and 0,9 kg/cap/day for the serviced areas and 0,47 kg/cap/day for the squattered areas in 1997.

Table 21. A survey on the solid waste collection in Arusha (Leaning 1977).

Area	Serviced population	Weight collected per pick-up (kg)	Number of samples	Minimum number collected per week	Total collected per week (kg)	Generation rate (kg/cap/week)
1	not known	2540	1	3	7620	not known
2	4572	2996	4	3	9000	1,89
3	5238	2808	6	6	16850	3,22
4	4283	3900	3	3	11700	2,73
5	not known	2453	3	2	4910	not known
6	3044	1926	3	3	5780	1,90
7	5017	2580	1	1	2580	0,51
8	2500	1248	5	6	7490	3,00
9	2000	1220	1	3	3660	1,83
10	4030	2070	2	1	2070	0,51
11		No samples collected				
Total	30864				71660	2,32 or 0,33 kg/cap/m^3

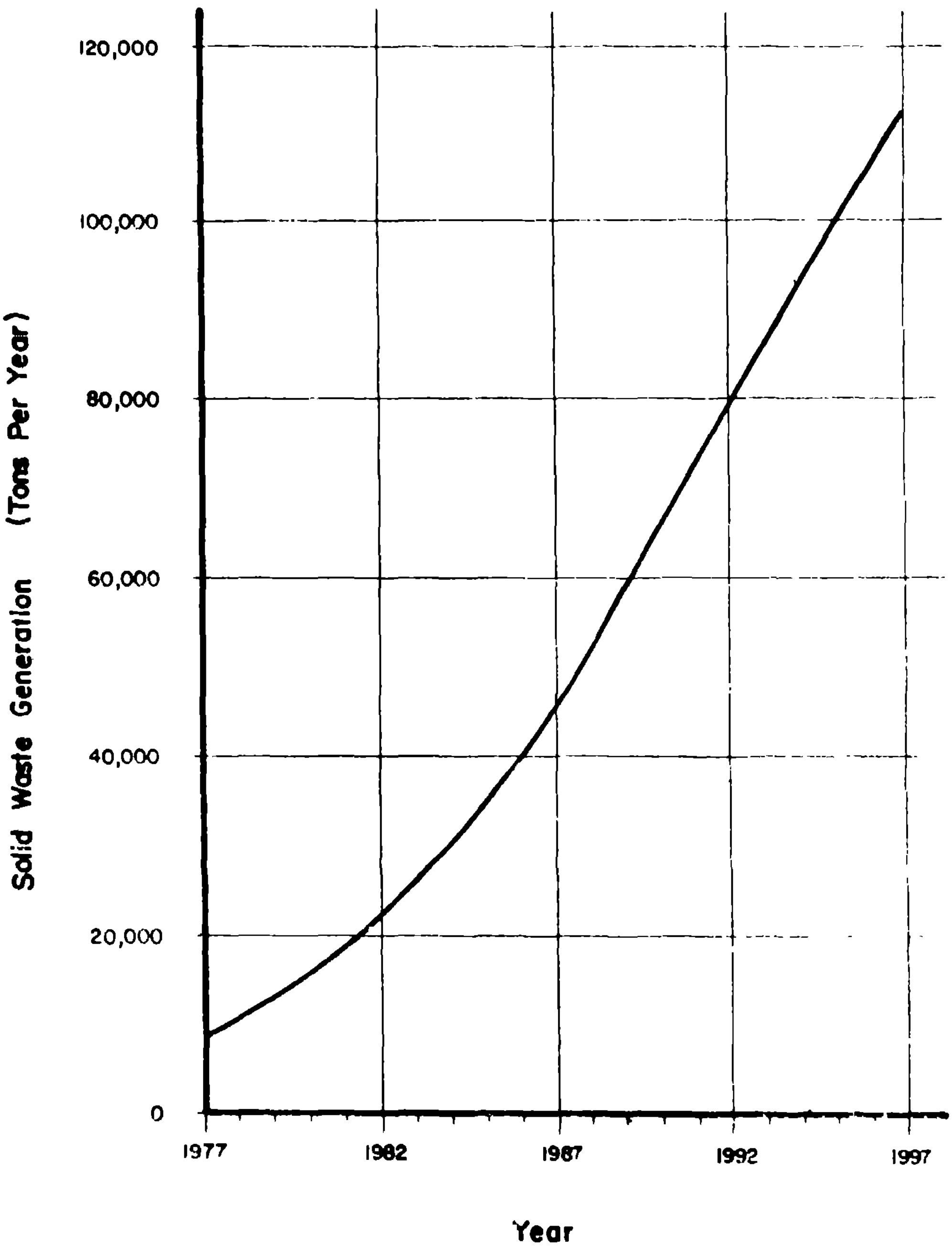


Figure 17. Projection of total solid waste generation for Arusha town (Leaning 1977).

Compared to the available literature, the generation rate figures for the serviced areas are quite close to the figures obtained from other low income countries. The generation rate for low income countries varies from 0,4 to 0,6 kg/cap/day, and from 0,5 to 0,9 kg/cap/day for middle income countries (Cointreau 1982). This means that the generation rate for squattered areas is about 50 % of the generation rate for low income countries. This is true because in squattered areas there is low commercial activity and door to door scavenging is more pronounced.

4.3 Storage

Each house premise is supposed to have a container in which wastes have to be stored. The town council is supposed to provide standard bins with lids to the house owners at a subsidized rate. Due to low financial ability and scarce resources in the manufacturer's side, these bins are not readily available. Instead, 200 l steel drums (normally emptied bitumin containers) are sold to the house owners at a rate of 50 Tanzanian shillings (1 USD = 17 TAS). Even these drums are not readily available, and therefore individual house owners make arrangements for their own containers. Problems exist with these containers as other individuals take the containers illegally at night to fabricate other items according to their interests (e.g. local cookers using charcoal as fuel). Some of the containers are perforated because all wastes are dumped into the same containers and some of them are semi-liquid. This reduces the weight of filled containers and also discourages illicit distillers who otherwise might take the containers.

Due to these problems, many places are without containers and wastes are dumped in open areas nearby, usually on the curbside of streets. Street sweepings are collected in small heaps where the collection truck crew can easily load the trucks. When the collection truck makes a round trip, the crew empties the containers, recollects the heaps and wastes that have been spread all around the containers and loads the truck.

Two hospitals exist in the area and their wastes are supposed to be incinerated. Due to problems with incinerators, the hospitals are serviced by the town council in the similar way as individual domestic refuse producers. However, the hospitals have aluminium containers of 40 l with lids.

Industries collect their wastes in their premises in a way which can suit to their purposes.

Some people use small pits to accumulate their wastes, particularly in low income areas. People also collect and burn their wastes in small heaps at intervals best suited to them. Some wastes accumulate in different areas: open drains, low income areas and sometimes in market areas.

The storage in Arusha town is quite similar to the system employed in Moshi with the same problems. The following figures show some elements in the storage system.

Figure 18. Drums used for storage are seen during a loading process.

Figure 19. 40 l containers for hospital wastes in Moshi town.

Figure 20. Some wastes strewn on the side of a building in Arusha town.

4.4 Collection and transportation

4.4.1 Moshi town

The town council provides trucks to make a round trip to various residential, commercial and institutional areas. All trucks are manually loaded. Each truck has six labourers and one driver. When the truck goes through the areas with containers and heaps of collected refuse, the labourers load the truck. After the truck is filled to about 80 % of its total capacity, it goes to the dumping site for final disposal. Only one of the three trucks is self tipping. The rest are manually loaded and unloaded. A tractor with a trailer (shuttle system) often services the central market.

Most of the fleet is over ten years old. In a typical working day, about 60 % of the usable fleet is down waiting for maintenance or repair. Due to difficulties, such as lack of spareparts, a vehicle can be down for over a week waiting for minor repairs and a month for major repairs.

The round trip travel time is one to two hours for most of the collection routes, and the round trip travel is about ten kilometres. During the rainy season access to some areas and to the disposal site is difficult. Although there is no delay in traffic, occational breakdowns as well as manual loading and unloading affect the productivity of the transport system.

Figure 21 shows waste recollecting and loading in an area in Moshi town.

4.4.2 Arusha town

The Arusha Municipal Council provides trucks to make a round trip to the various residential, commercial and institutional areas. All trucks are manually loaded. Each truck has five labourers and one driver. As the truck goes round, it is loaded in a similar way as it is in Moshi town, and after it is about 80 % full it goes directly to the dumping site for final disposal. A tractor and trailer shuttle system services the central market.

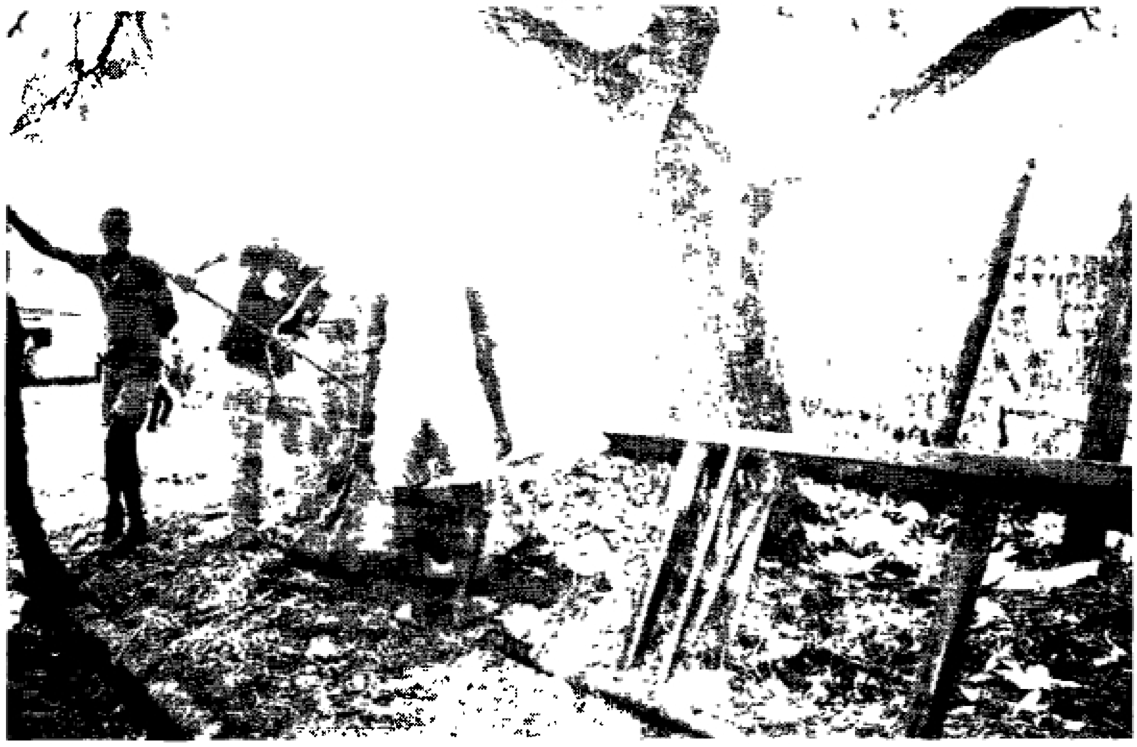


Figure 21. Waste dumped under a tree in Moshi town. The crew is recollecting wastes and loading the truck.

Most of the fleet is over ten years old. On a typical working day about 30 % of the usable fleet is down waiting for maintenance. A vehicle can be down for about 2 days waiting for minor repairs and over a month for major repairs. This is due to the lack of basic spareparts.

In Arusha town the round trip travel time is 2 to 3 hours for most collection routes, and the round trip travel is about 15 kilometres. During the rainy season, access to the disposal site is very difficult due to the black cotton soil. There is no delay in traffic. Slow loading and unloading system here affects the productivity in the same way as in Moshi town.

4.5 Treatment and disposal

4.5.1 Moshi town

Although wastes from all sources can reach the dumping site, there is no special treatment for wastes from any source.

A crude open dumping site is located on the terraces of the Njoro stream to the southeast of the town (appendix 1). All refuse collected and transported by the town council is finally disposed off at this site. Private people and industrial enterpreneurs who wish to transport and dump their wastes to the same site are allowed without any restrictions.

Pits dug at the dumping site show weathered rock within 1,0 - 1,5 m from surface, and in some other areas hard rock outcrops. This does not rule out possible fissures in the rock. The site is sloping towards the perennial Njoro stream flowing some 200 m away. Adjacent to the dumping site is the Tanzania Tanneries Limited with its dumping site separated by a wire fence from the central dumping site. On the other side of the dumping site is the Moshi town wastewater treatment plant. Some boreholes exist in Moshi town and one of them is about 400 m from the dumping site. The lithology indicates confined aquifers only. During the rainfall periods, surface runoff from the site reaches the Njoro stream. Some of the rainfall water percolates through the decomposing heaps and finds its way down at the boundary of hard rock and the surface complex. There is fire at different areas of the dumping site. This reduces odours and flies, but it is partly extinguished during the rains.

Water samples from the stream at different locations near the disposal site and from a spring starting nearby (figure 22) were collected and analysed. Results are given in table 22.

Only few parameters have been analysed because of difficulties in analyses. For example heavy metals were not possible to analyse because of a problem related to atomic absorption photometers, and BOD_5 could not be analysed for some samples simply because they reached the laboratories after too long a time.

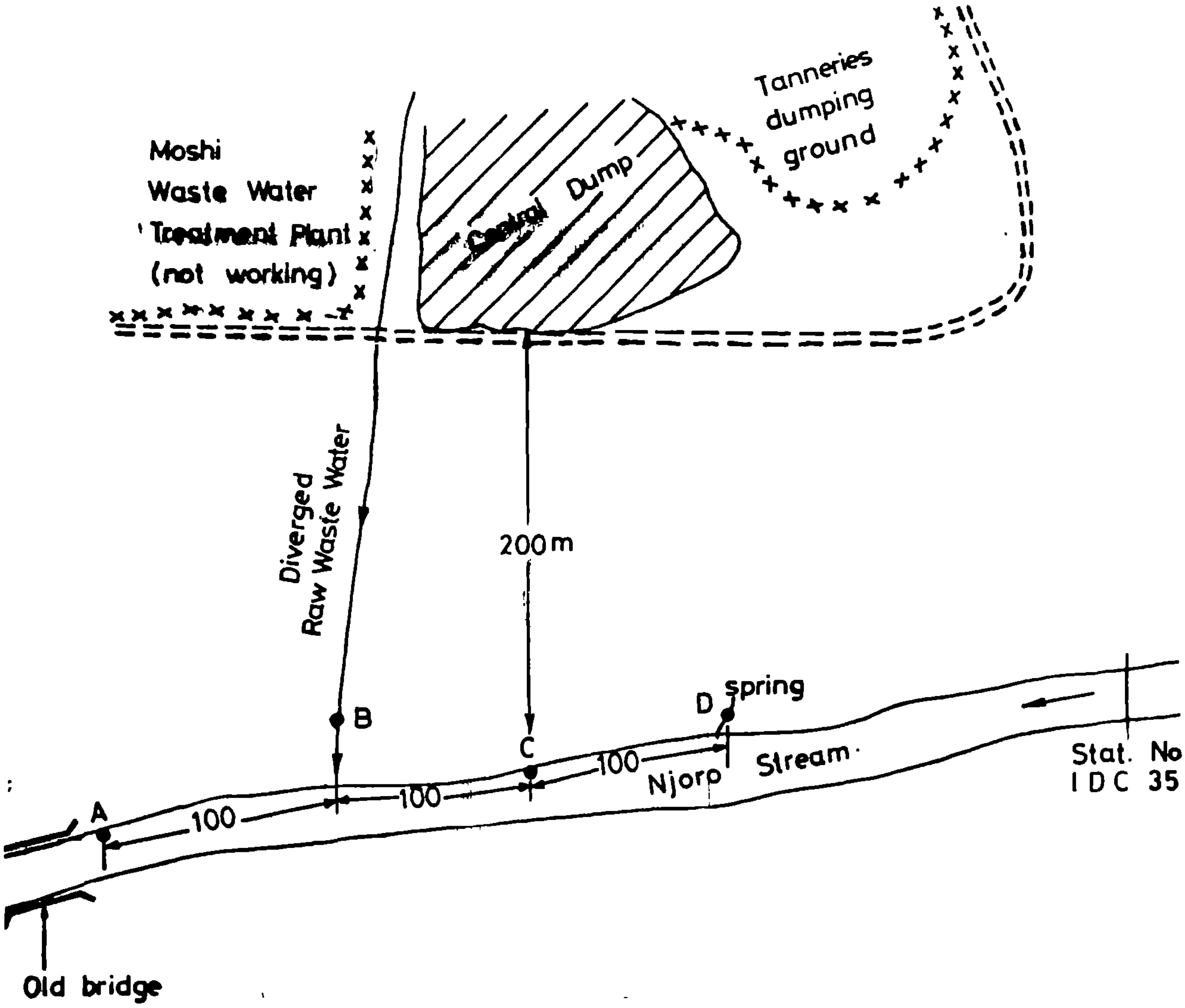


Figure 22. Location of sampling points A-B-C-D in the Njoro stream (not to scale).

It can be noted however from the few parameters (table 22) that after some rains there is an increase in the parameters. It cannot be immediately concluded which source brings the increase, and even the pattern by which the parameters vary is not convincing at all. It can therefore be stated only in general that after some rains there is a change in the parameters indicating possible interference from nearby utilities.

Table 22. Results of water analyses.

Parameter	Sampling point (figure 22) A	B	C	D	Laboratory and date of sampling	Remarks
Chloride (mg/l)	16,0	36,0	16,0	48,0	Nairobi 14.11.1985	No rains
	21,3	23,4	326,4	106,0	Dar es Salaam 15.12.1985	Rains 2 days back
	80,3	39,2	9,2	9,2	Dar es Salaam 20.11.1985	No rains
	8,2	7,8	7,8	73,2	Tanzania Pesticides Research Institute 7.1.1986	Rains 2 days back
NH_4^+-N (mg/l)	3,1	70,0	2,2	3,9	Nairobi 14.11.1985	No rains
	12,0	12,0	144,2	47,0	Dar es Salaam 15.12.1985	Rains 2 days back
	0,3	Nil	0,6	Nil	Dar es Salaam 20.11.1985	No rains
Nitrate-N (mg/l)	3,1	1,8	1,2	2,8	Dar es Salaam 15.12.1985	Rains 2 days back
	0,8	0,9	0,3	0,6	Dar es Salaam 20.1.1986	No rains
$KMnO_4$ (mg/l)	4,6	21,0	5,9	4,5	Nairobi 14.11.1985	No rains
	4,2	130,0	3,2	8,4	Dar es Salaam 20.11.1985	No rains
Conductivity (μs/cm)	500,0	650,0	140,0	165,0	Dar es Salaam 20.11.1985	No rains
pH	6,8	7,56	7,49	7,65	Tanzania Pesticides Research Institute 23.1.1986	No rains
BOD_5 (mg/l)	4,8	>180,0	0,7	3,1	Tanzania Pesticides Research Institute 23.1.1986	No rains
COD (mg/l)	96,0	>690,0	229,0	198,0	Tanzania Pesticides Research Institute 23.1.1986	No rains

Discharge at the sampling points in November and December was on average:

A	0,86 m^3/s
B	0,02 m^3/s
C	0,84 m^3/s
D	0,02 m^3/s

Figures 23 and 24 show the dumping site and the Njoro stream.

Figure 23. The dumping site. The trees on the background mark the Njoro stream. Burned wastes and scavenging can also be seen.

Figure 24. Njoro stream.

4.5.2 Arusha town

In Arusha also there is no special treatment for collected wastes. A crude open dumping site is located at about 7 km south of the town centre (appendix 2). Refuse from all sources is dumped there. Private people and industrial enterpreneurs who wish to dump their wastes to the site are allowed without any conditions.

Although there is no sign of rock outcroping in the site, pits dug in the site show weathered rock within the depth of 2 m from the surface, overlayed by layers of murram type of soil and black cotton soil. The site slopes to some depressions which join the Themi river passing about 500 m away. Although there are no important structures near the dumping site, part of it has been allocated for the construction of flats and the construction work is on progress. This necessitates the shifting of the dumping site. The existing plans indicate shifting the site by about 2 km further south. During the rainfall periods, surface runoff finds its way to the Themi river through the depressions. Figures 25 - 27 show the Arusha dumping site and the pits dug on the site.

Figure 25. A truck with an open platform unloading at the Arusha dumping site.

Figure 26. Construction has started on a part of the Arusha dumping site.

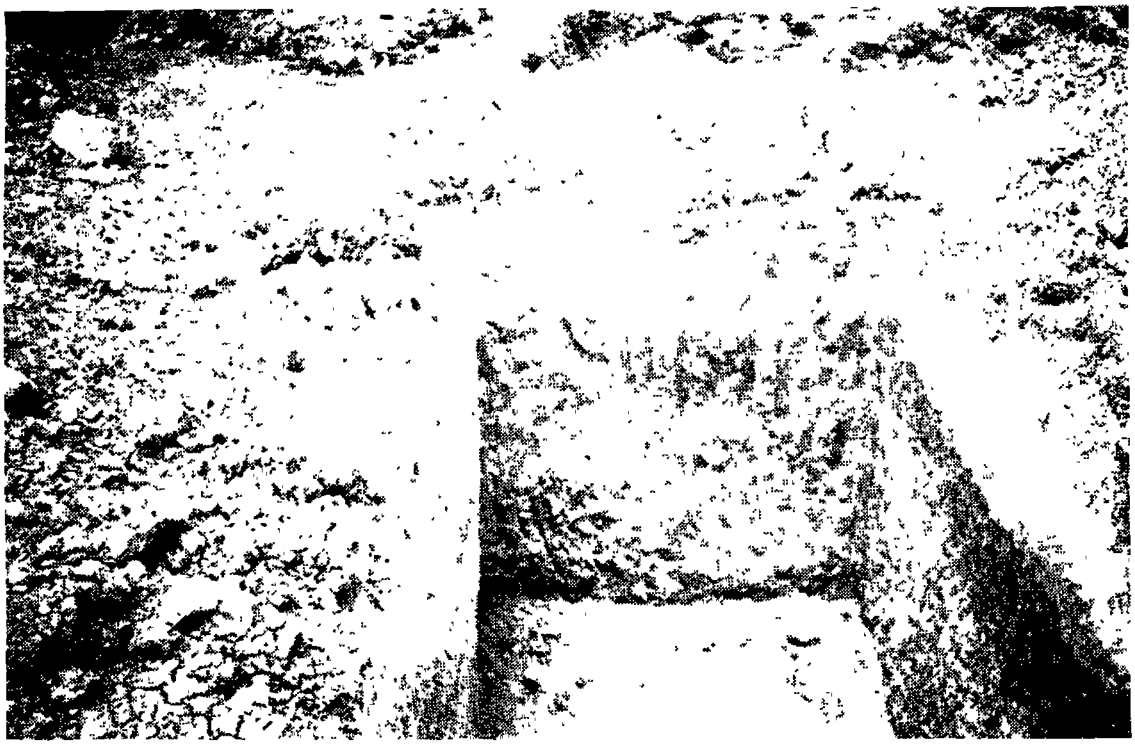


Figure 27. Pits dug at the dumping site in Arusha.

5 INFLUENCE OF SOLID WASTE DISPOSAL ON WATER RESOURCES

Large scale solid waste disposal facilities include open dumps, incinerators and landfills. Ultimately all solid waste is disposed off on land, either in the original form or as incinerator ash.

Open dumps have proved to be disastrous both to the ground and surface water quality. In open dumps the wastes are exposed to precipitation which greatly increase the amount of leachate produced (FAO 1979). The soil profile is often unable to provide sufficient treatment to the concentrated leachate from open dumps. The procedures used in a sanitary landfill operation were developed partly as a result of experience with pollution caused by open dumps (FAO 1979). Until now there have been several studies on the production of leachate in landfills. The data obtained from several places show that leachate from landfilled refuse exhibit a wide range of chemical concentrations. This variation is caused by many factors such as refuse characteristics, hydrogeology of the site, climate, season, age of the site, height of the refuse and moisture content routing of the refuse. The maximum concentration of most of the constituents occurs approximately after 90 days of operation, after which it remains constant for about 500 days followed by a slow decline in concentrations (Polprasert and Carlson 1978). Table 23 shows different ranges in composition of different landfill leachate.

Table 23. Range of physical and chemical composition of sanitary landfill leachate (Polprasert and Carlson 1978).

Constituent	Cincinnati ENGELRECHT and AMIRHOR (1975)	Midwest USA STEINER et al (1971)	Cedar Hills FINGER (1975)
COD	40 - 89 250	100 - 51 000	2 940 - 50 000
BOD_5	81 - 33 360		1 600 - 29 800
TOC	256 - 28 000		
pH	3,7 - 8,5	4,0 - 8,5	5,4 - 6,6
TS	0 - 59 200	1 000 - 45 000	1 610 - 29 990
TDS	584 - 44 900		
TSS	10 - 700		740 - 14 990
Specific conductance	2 810 - 16 000		

Table 23. Cont'd.

Constituent	Cincinnati ENGELBRECHT and AMIRHOR (1975)	Midwest USA STEINER et al (1971)	Cedar Hills FINGER (1975)
Alkalinity ($CaCO_3$)	0 - 20 850		
Hardness ($CaCO_3$)	0 - 22 850	200 - 5 250	
Total-P	0 - 130	5 - 130	1,4 - 10
Ortho-P	6,5 - 85		
NH_4-N	0 - 1 106	20 - 500	30 - 560
NO_3+NO_2-N	0,2 - 10,3		
Ca	50 - 7 200		
Cl	4,7 - 2 467	100 - 2 400	
Na	0 - 7 700	100 - 3 800	
K	28 - 3 770		
SO_4	1 - 1 558	25 - 500	195 - 2 610
Ni	0,09 - 125	0,01 - 0,8	0,03 - 1,76
Mg	17 - 15 600		
Fe	0 - 2 820	200 - 1 700	250 - 2 115
Zn	0 - 370	1 - 135	1,2 - 149
Cu	0 - 9,9	0,1 - 9,0	<0,01 - 0,38
Cd	<0,03 - 17		<0,01 - 0,12
Pb	<0,1 - 2,0		0,03 - 23,35
Cr			<0,01 - 0,29
Flow m^3/day			4,3 - 85,3

All constituents expressed as mg/l except pH and specific conductance, which is as 10^{-3} millimhos per cm.

It can be seen from table 23 that the leachate from the landfill areas exhibits a wide range of chemical concentrations. The concentrations change with time, infiltration inflow, seasonality, overall waste decomposition and waste consolidation. The leachate concentrations are highest just after the waste deposit becomes fully saturated and gradually decrease as the soluble components slowly seep away (Cointreau 1982).

5.1 Groundwater pollution

Most potential groundwater contaminants are released at or slightly beneath the lands surface. Here the wastes are subjected to the process of leaching and percolation which may lead to their introduction into the groundwater. As they move through the unsaturated zone above the groundwater table, it is the tendency of contaminants to atenuate; a process which sometimes eliminates potential contamination sources as serious problems because the contamination simply does not reach the groundwater in sufficient strength. Physical, chemical and biological aspects influence the movement of contaminants through the soil of the unsaturated zone and in the aquifers (FAO 1979).

5.1.1 Physical aspects

In the unsaturated zone the movement of solute is primarily vertically downwards from the surface and a mild degree of horizontal displacement. Hydraulic and mass transport properties influence the degree of pollutant movements (FAO 1979).

a) Hydraulic conductivity and hydraulic gradient (Darcy's Law): If the solute is available along with moisture source, like rain, and the hydraulic conductivity is high, the pollutant is likely to penetrate the unsaturated zone deeply depending on the moisture content. Lower moisture content results in a greater degree of downward movement of the solute (as in sand).

b) Amount of active pore spaces compared to amount of inactive pore spaces or dead-end spaces: Aggregated soils having large pores readily transmit water, and much smaller or isolated pores admit solute primarily via molecular diffusion. In the former, solute moves through the soil more quickly due to decreased active moisture content while in the latter some of the solute lags behind as it gets trapped in the inactive pores.

c) Degree of heterogenity of the soil: Where it refers to the pore size distribution it results in the "dead end" pore effect. Where it refers to the sediment stratification it results in spatially varying moisture profile and hydraulic conductivity which influences the rate of solute movement.

d) Boundary conditions to the unsaturated zone: This determines whether water and solute will be moving upwards or downwards at a given time. In humid areas, after the first few centimetres of the soil depth, the primary direction of flow is downwards while in arid regions it will be upwards during the period of high evapotranspiration and downwards during periods when water is available.

e) As it moves through the unsaturated zone the solute will spread out, maybe due to "dead-end" effect or due to dispersion.

The climate of regions affects the physical properties. The more rainfall occurs the deeper a solute can be expected to penetrate a given soil. If the solute is within the top 30 cm of the soil it may travel back to surface due to evaporation. If enough rain falls to remove the solute from this zone, it will probably reach the groundwater. Low intensity rainfall is more efficient in moving contaminants (FAO 1979).

The climate also affects the hydraulic properties of the soil water, viscosity and surface-tension, since they depend on temperature.

It may take years for a solute to percolate through the zone of aeration even in the absence of chemical effects due to slow movement of percolating water. Even so, under favourable circumstances the solute may reach the water table in a matter of hours although days or weeks is a more realistic time span. Once the pollution reaches the saturated zone it usually spreads out and moves in the general direction of groundwater movement, often towards natural discharge areas of the aquifer which may be a stream, a river, a lake, a spring or wetlands or towards groundwater extraction activities in the vicinity, subjected to a number of physical factors similar to those in the unsaturated zone.

In the porous media observations indicate that the natural rates of movement of pollutants vary from 1,5 m (5 ft) per year to 1,5 m (5 ft) per day, and in fractured media up to 300 m (1000 ft) per day (FAO 1979).

According to Qasim and Burchinal (1970), Calvert (1932) reported an increase in hardness, calcium, magnesium, total solids and carbon dioxide in a well 152 m away from an impounding pit for a carbage reduction plant. According to Qasim and Burchinal (1970), Lang (1941) reported the pollution of a well 610 m (2000 ft) away from a fill in Germany. Also Qasim and Burchinal (1970) reported that Mertz (1954) studied the leaching of sanitary landfills and determined that if fill materials are in intermittent or continuous contact with groundwater, they may cause water in the immediate vicinity of the fill to become grossly polluted and unfit for domestic or irrigation use. Also Qasim and Burchinal (1970) reported the studies conducted by Roessler (1954) near Krefeld, Germany, where he observed that refuse dumping caused deterioration of surface water 4 km (2,5 miles) downstream from a dumping site.

However, according to Pickford (1977) wastes with potential to cause pollution by increased concentration of organics and inorganics to levels where water becomes unfit for drinking include domestic refuse, night soil, sewage sludge and most industrial wastes. The leachates from this category of wastes may have high biochemical oxygen demand (BOD), high concentrations of ammonical nitrogen, chlorides and sulphates. Water supplies will usually be safe if the leachate passes through about 15 m of granular material and is then diluted by mixing with other groundwater; a distance of 800 m between the tip and the abstraction point is usually enough for this dilution (Pickford 1977).

5.1.2 Chemical aspects

As water moves through the unsaturated soil and in ground aquifer, its composition changes. It will be in contact with various soil and rock minerals, with the organic and inorganic constituents of the soils, the result of which is chemical reaction followed by solution and the water accumulates numerous dissolved impurities. However, it is the leaching process which leads to the background concentration levels of organics, salts, metals etc. Important chemical phenomena include volatility, acid and bases, solubility and precipitation-solution, oxidation-reduction (redox), surface phenomena including ion exchange and adsorption and particular aspects of organics and heavy metals including hydrolysis (FAO 1979).

Kjeldsen and Christensen (1984) conducted some experiments to obtain basic information about the behaviour of pollutants in soil-groundwater system. A series of saturated laboratory soil columns loaded with acid phase leachate under anaerobic CO_2-saturated conditions was studied in terms of solute breakthrough curves and final pollutant in soil profiles.

Four soils were studied and they exhibited significantly different capacities for attenuating pollutants. Ammonia, sodium and boron were attenuated only by adsorption and organic matter by both adsorption and degradation. Dissolved solids, specific conductivity, potassium, calcium, magnesium, iron and manganese were, besides adsorption, subject to precipitation-dissolution process. For iron and manganese, the latter process was in combination with redox processes. Zinc and cadmium were extensively attenuated probably due to a combination of adsorption and sulphide precipitation. With a few exceptions, chloride, dissolved solids, specific conductivity, organic matter (COD) and sodium were the most mobile constituents of the leachate exhibiting migration velocities of 80 - 100 % of the water flow velocity (Kjeldsen and Christensen 1984).

5.1.3 Biological aspects

Biological activities influence the groundwater in different ways. First there is the threat of transmission of pathogenic organisms from organic wastes to the groundwater. Secondly there is the threat of increased concentrations of organic materials which originate as wastes. These two mechanisms are associated with each other. Thirdly there is the presence of micro-organisms which act in the oxidation-reduction reaction of organics and inorganics in the subsurface environment (FAO 1979).

The organisms living in and on the soil complex including bacteria, algae, soil animals, actenomycetes, fungi, protozoa and higher plants provide some protection to the groundwater by oxidising organic and inorganic compounds. For these organisms to function properly, they need oxygen, sunlight and space. As most of the systems are limited, their ability to function is also limited. Also, most microbial population is concentrated on the top 15 cm soil layer which is rich in organic matter, and numbers decrease rapidly with depth. Thus the location of the organic or inorganic source relative to the top soil is important.

Excessive accumulation of organic load reduces the soil aeration. Application of environmental toxins such as heavy metals is another serious threat to the biological filter (FAO 1979).

As regarding transmission of pathogenic organisms it is generally agreed that the soil complex provides some protection against the threat but it by no means eliminates it (FAO 1979).

The potential hazards from pathogenic agents would primarily depend on their ability to survive, retain the infection properties in the landfill environment and then move through the landfill into adjacent ground or surface waters. Although most micro-organisms have been found to be in the inhibitory stage in the leachate environment, a study by Polprasert and Carlson (1977) found that they could be reactivated again by diluting the leachate with tap water and aerating the mixture for a few days. Further biochemical analyses of some lactose non-fermenting colonies from the diluted leachates using API20E System (Analy-tab Products Inc; N.Y) revealed the presence of various species of enteric bacteria such as Salmonella, Shigella, Yersinia, Escherichia, Secretia and Pseudomonas. Some of these are pathogenic to man. The findings indicate that pollution (or dilution) of leachate to ground or surface waters may lead to health hazards because these circumstances would provide favourable conditions for the micro-organisms to overcome their previous inhibitions to growth and would proliferate again.

According to Polprasert and Carlson (1978), studies by Boventre and Kempe (1960) indicate that 100 bacteria cells are needed to produce one "minimum infective dose" (MID) under optimum conditions. Also according to Polprasert and Carlson (1978), experiments by Schaub and Sagik (1975) indicated that clay-absorbed viruses retained their infectivity in mice, and studies by Plotkin and Katz (1965) indicated that only one virus constitutes a minimum infective dose. Cointreau (1982) reported that Helminth ova have shown to survive both in anaerobic digestion and air drying and to be infective after several years of storage.

As regarding hazardous industrial waste disposal, in early 1984, 881 abandoned sites were evaluated using "Hazardous Ranking System" designed by the United States Environmental Protection Agency (EPA), to determine priority remedial and removal actions. According to the data obtained, 450 sites may have adversely affected surface water, with an estimation of 6,5 million people potentially being exposed, and 526 sites may have an adverse effect on the groundwater, potentially exposing an estimated 8,2 million people (Helsing and Shen 1984).

5.2 Surface water pollution

The normal source of leachate causing this pollution is rain falling on the surface of a landfill and percolating through it, and passing over an impermeable base to water at a lower level. Some of the rainwater is lost through evaporation and transpiration and therefore only a proportion of the precipitation emerges as leachate. This can be avoided by diverging all water courses crossing the site, and by constructing an impermeable barrier on the downstream end of the landfill. The final level of the landfill has to be graded such that precipitation is drained across the surface and only a small proportion percolates below the level needed to produce a leachate. Polluted groundwater discharging to a surface water source can also lead to surface water pollution. Figure 28 shows how to protect surface water from pollution caused by surface run-off passing over a land filled with refuse (Wilson 1981).

5.3 Effects of polluted water source

The definition of water pollution has to be tied to the use of water, describing the effects in terms of use and associated contaminants.

5.3.1 Effects on public health

Biological contaminants from domestic sources constitute the most important source of poor health associated with water. Today, 1000 million children have little or no access to safe clean water. 100 million more people today have to drink dirty water than ten years ago. There are one billion cases of diarrhoea every year in the third world, causing 25 million deaths which include 16 000 small children deaths every day. Of those who have access to clean water, tens of millions have to carry it by hand over many miles every day (Braithwaite 1985).

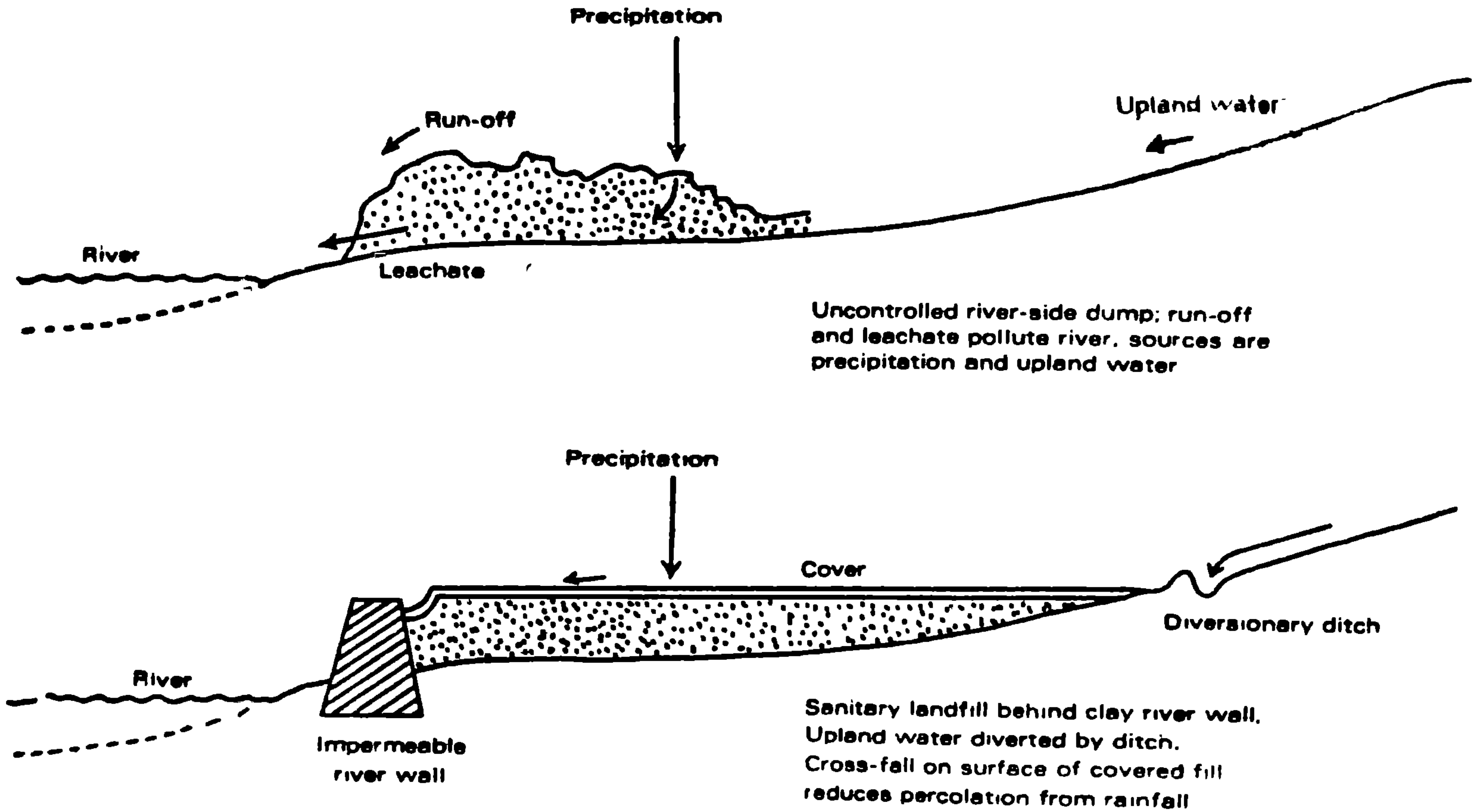


Figure 28. Control of surface water pollution (Wilson 1981).

A contaminant like nitrate nitrogen which is mobile (moves freely even with flowing groundwater) and in high concentrations (10 mg/l as NO_3^--N) is a cause of methaemoglobinaemia in infants. It may cause bluish skin if not too far advanced, or in the acute stage it may lead to brain damage and ultimately death. It is also possible that in high concentrations it can be metabolised to a nitrosamine, a potential carcinogen (FAO 1979).

Organic and inorganic chemicals from industries are other health hazards having proven toxicological effects to man and sometimes may cause death. Some of the heavy metals like mercury, lead, cadmium and silver are known to be highly toxic. Arsenic is a cumulative poison and it has been shown to be a possible carcinogen (Seppänen 1985). Barium is highly toxic. Chromium is hazardous to marine life and toxic to plants.

In order to make sure that water sources are protected from pollution, the Ministry of Water and Energy has together with the Ministry of Health formulated Domestic Water Health Standards and Effluent Standards. The standards have been passed by an act of parliament, namely the Water Utilization (Control and short title Regulations) act 1974 and the amedment of March 1982. Appendix 4 shows the Domestic Water Standards.

5.3.2 Effects on agriculture

The use of water for irrigation is widespread. As amounts of solids increase above a certain limit in irrigation water, the crop yield decreases. Like animals, plants require a trace of inorganics. If they are oversupplied, or with held, crop yield decreases. Fish and other aquatic life is affected in a similar way (Seppänen 1985). Figures 29 - 31 show salt tolerances for different crops.

Once the soil is saline, a leaching programme has to be arranged if the soil has to be reclaimed. The leaching process is expensive and it removes the useful nutrients in the soil in addition to the unwanted salts.

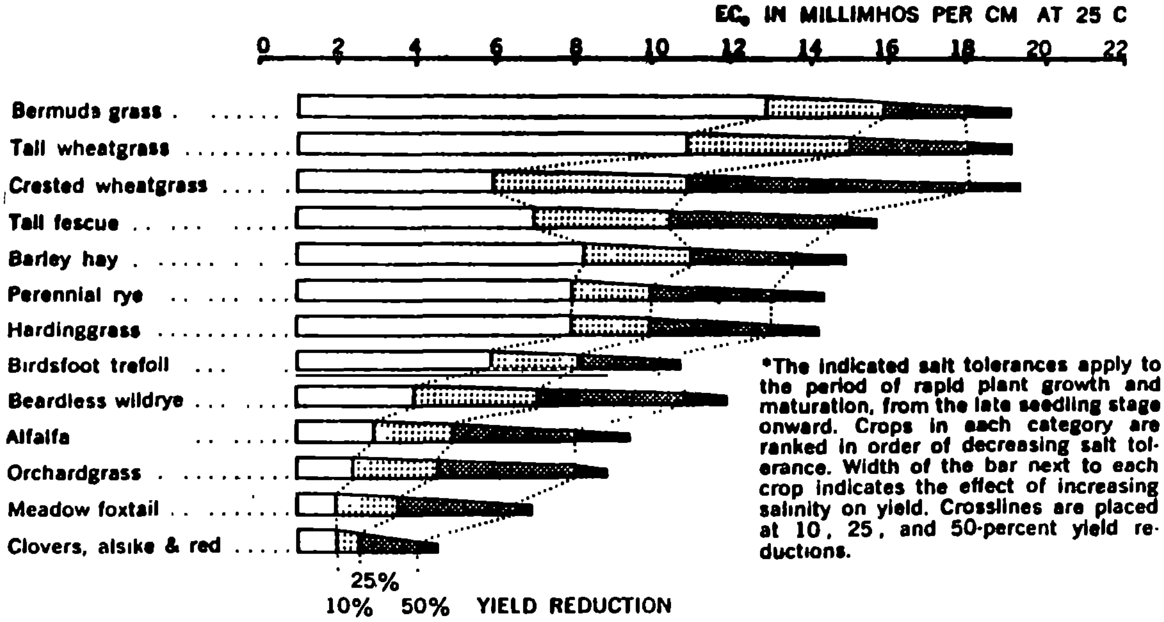


Figure 29. Salt tolerances for forage crops (Seppänen 1985).

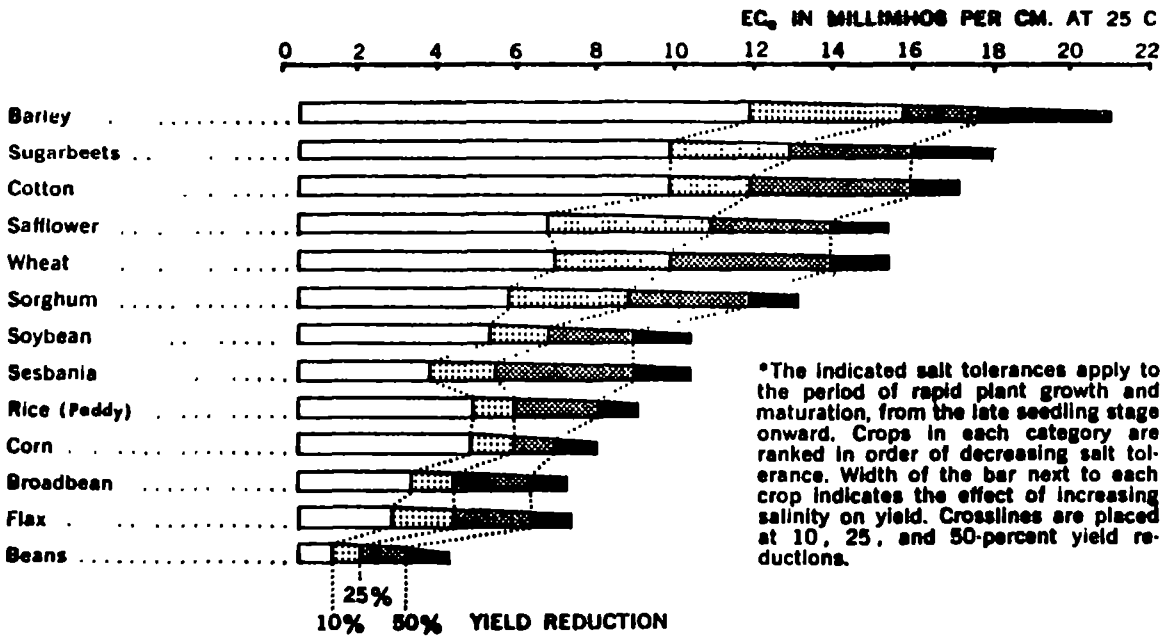


Figure 30. Salt tolerances for field crops (Seppänen 1985).

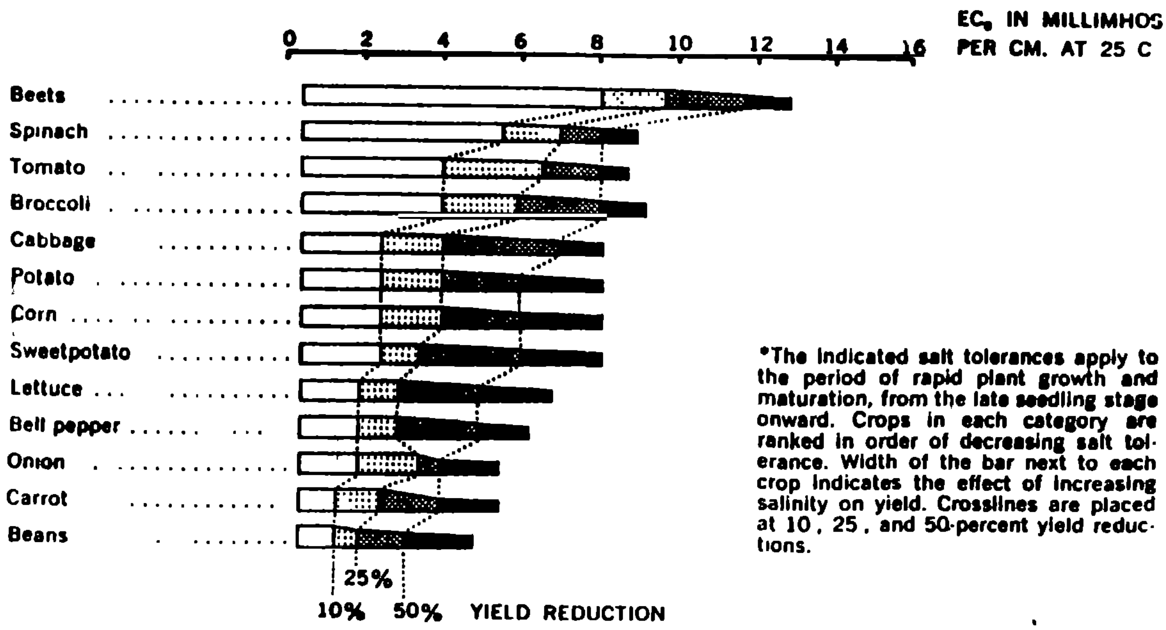


Figure 31. Salt tolerances of vegetable crops (Seppanen 1985).

5.3.3 Effects on fish and other aquatic life

Natural water maintains a wide variety of aquatic life including fish, bacteria, algae and protozoa, all of which are in a dynamic equilibrium with the environment. Temperature, chemical composition, dissolved oxygen and pH are important parameters in the aquatic environment. Wastes entering the water body vary considerably and may be disastrous. If the natural chemical and biological equilibrium is upset, direct or indirect damage to one or more of the species may occur. Direct damage occurs when substances accumulate in the water in concentrations toxic to the plant and animal life.

The distruction of plant and animal life will hinder or prevent natural self purification. The salts of heavy metals like beryllium, cadmium, lead, mercury, nichel, silver, gold, chromium, zinc and copper are toxic to fish at very low concentrations. For example, in one river only, 1 - 2 mg/l of copper was found to have completely exterminated all animal life for 16 km (10 miles) downstream and decimated the algae concentrations (Bridgwater and Mumford 1979).

An added problem with heavy metals is the facility of certain organisms to concentrate them up to about x 10^5. An example of this occurred in Japan between 1953 and 1960, when a large number of cases of neurological disease over 100 of which were fatal took place amongst villagers around Minimata bay. This was caused by the ingestion of methyl mercury, dumped in chemical wastes in the bay and accumulated in fish and shellfish which were then eaten (Bridgwater and Mumford 1979).

Other organic chemicals especially chlorinated hydrocarbons are equally toxic and tend to accumulate in the environment. Table 24 shows the concentrations at which common materials show toxic effects to different organisms (Bridgwater and Mumford 1979).

Table 24. Concentrations (mg/l) at which common materials show toxic effects in various organisms (Bridgwater and Mumford 1979).

	Bacteria Escherichia coli	Green algae Scenedesmus quadricauda	Daphnia magna	Protozoa microregma
Copper (Cu)	0,08	0,15	0,1	0,05
Zinc (Zn)	1,4 to 2,3	1 to 1,4	1,8	0,35
Chromium III (Cr)		4 to 6	42	37
Cyanide (CN^-)	0,4 to 0,8	0,16	0,8	0,04
Cyanate (CNO^-)	10	520	23	21
Sulphide (S^{--})	93	40	26	
Phenol		40	16	30
Toluene	200	120	60	
o-Xylene	500	40	16	10
m-Xylene		40	24	70
p-Xylene		40	10	50
Amyl alcohol		280	440	20
Formic acid		100	120	
Butyric acid		200	60	
Butyl acetate		320	44	20
Amyl acetate		180	120	40

5.3.4 Effects on industries

Water quality requirements in industrial uses depend on the quality of the industry. In general, food and other related industries need water with higher quality than other types of industry. Table 25 shows the water quality characteristics which have been used by the food canning industry.

Table 25. Water quality characteristics that have been used in the food canning industry (Seppänen 1985, extract from Water Quality Criteria 1968).

Characteristic	Concentration (mg/l)
Alkalinity ($CaCO_3$)	300
pH units	8,5
Hardness ($CaCO_3$)	310
Calcium (Ca)	120
Chlorides (Cl^-)	300
Sulfates (SO_4^{2-})	250
Iron (Fe)	0,4
Manganese (Mn)	0,2
Silica dissolved (SiO_2)	50
Phenols	*
Nitrate (NO_3^-)	45
Nitrite (NO_2^-)	not detectable
Fluoride (F)	*
Organics CCE (carbon chloroform extract)	0,3
Chemical oxygen demand (O_2)	accepted as received
Odour, Threshold number	*
Colour units	5
Dissolved solids	550
Suspended solids	12
Coliform count/100 ml	*

* As specified on Water Quality Criteria for public water supplies.

6 RECOMMENDATIONS TO IMPROVE SOLID WASTE MANAGEMENT IN MOSHI AND ARUSHA

6.1 Planning, organization and finance

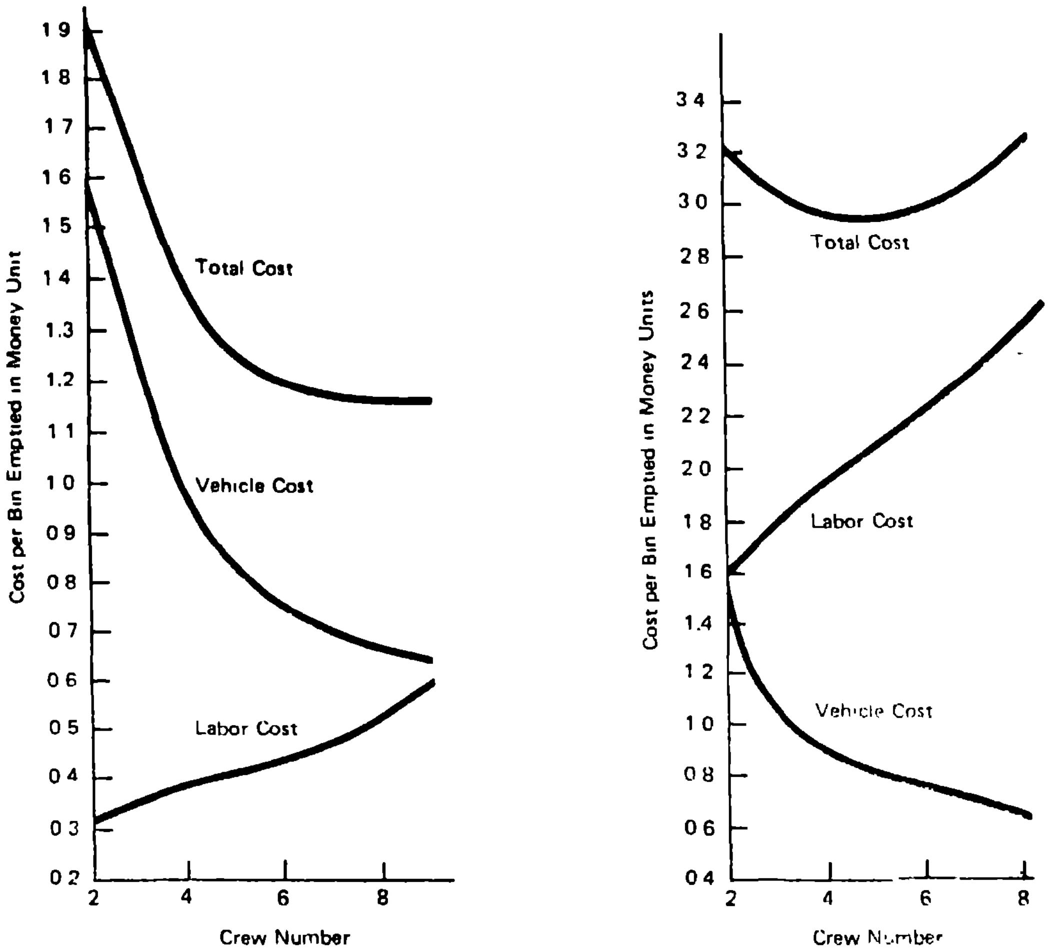
1) Planning

In order to establish priorities and set standards within the solid waste sector, the following issues have to be considered (Cointreau 1982).

- What categories of waste are included within the responsibility of the local government for collection and disposal?
- What level of control is desirable over waste categories that are not serviced by the public sector?
- What portion of the waste generated in each category is the target for collection service?
- What level of citizen participation and convenience is acceptable in the collection technique selected?
- What level of household storage service is acceptable in the collection technique selected?
- What frequency of collection is acceptable?
- Which environmental issues must be addressed in planning adequate system?
- What costs are involved?
- How much revenue can be collected and how it should be collected?

It is very difficult to link solid waste management service levels to health statistics. Therefore qualitative judgement concerning the local priorities should be addressed through a multidisplinary assessment by various officers and departments involved in health related services. Also the standard of service is very much linked to the funds that can be allocated to the solid waste sector. Therefore, after determining the level of service required, the budget is the least amount to achieve that level. More often the funding limit is established, and the level of service becomes whatsoever one can achieve within that amount.

Due to low budget ceilings, an appropriate technology has to be selected. Because solid waste collection and disposal have no economies of scale, costs should not be determined by the amount of refuse to be managed, but by optimization of the level of mechanization and intensity of labour. Where wage rates are relatively high compared to equipment unit costs, the number of persons for a given equipment should be minimized. Where wage rates are very low, labour intensive systems are more cost effective. Cointreau (1982) printed the chart developed by Flintoff to illustrate this point, and it is shown in figure 32.



For a low ratio of wage rate to vehicle cost, 1 10 the largest team achieves the lowest cost

For a high ratio of wage rate to vehicle cost, 1 2, a small team achieves the lowest cost

Figure 32. Labour/mechanization optimization (Cointreau 1982).

However, the appropriate technology does not always mean the lowest cost option. There are such issues as workers' health, safety and dignity. The choice must be that acceptable to the local population regarding these issues. Employment objectives may favour labour intensive solutions even if the solutions are not the least cost. Limitations on foreign exchange and capital may lead to favouring systems with higher total costs. Also bilateral aid or low-cost loans may bias selection towards capital intensive solutions (Cointreau 1982).

It is also necessary to have a phased action plan. The plan should consider expenditures for equipment, facilities, personnel, management incentives and disincentives as well as the financial base upon which the solid waste service relies. Actions ending with a major improvement without major capital investment should be readily incorporated. Such actions as optimization of supervisory personnel to direct labour, ratio of inspection personnel to service area, and ratio of maintenance personnel to equipment together with equipment to facilitate their work should be given initial emphasis. Record keeping on equipment and maintenance supplies, clarifying responsibilities such as making specific crews responsible for specific routes, and establishment of ordinances that spell out citizen participation are other important actions.

Refuse management takes a sizeable portion of the municipal budget (e.g. the refuse management in Moshi town takes about 17 % of the total budget). This demands a good accounting procedure and continuous planning. The findings of the plans have to be included in the budget process. It is therefore necessary to have a planning unit within the system, and accessibility to the decision-making process on budget allocations should be possible.

2) Organization structure

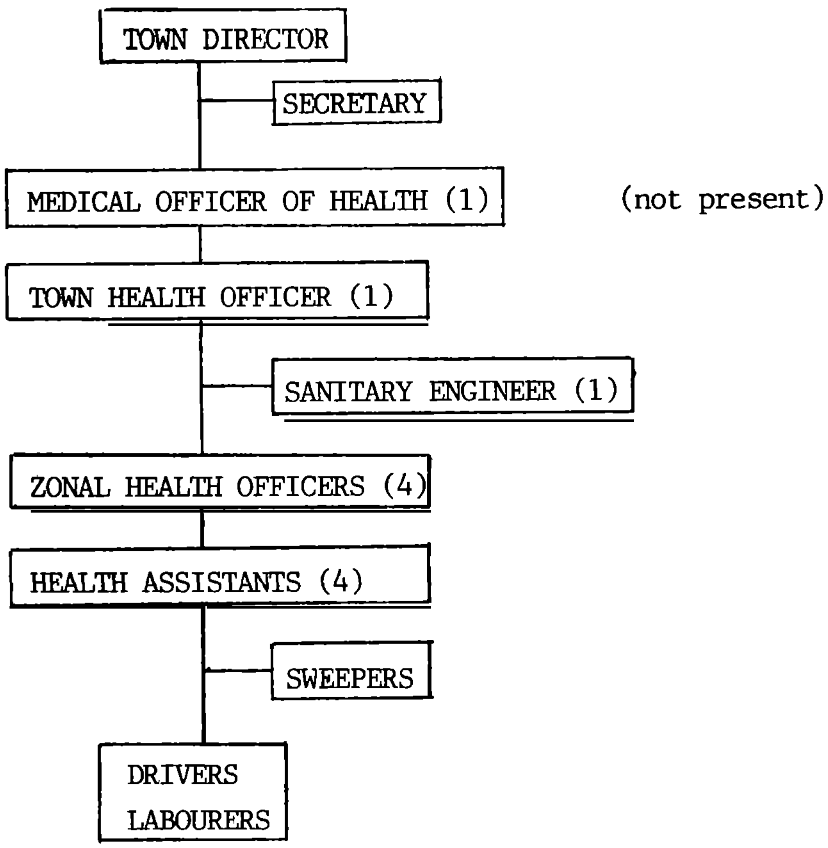
There should be a good organization structure. Designation of responsibility and authority should be very clear.

In Moshi and Arusha the current administrative responsibilities for refuse collection and disposal lie with the town/Municipal Health Department. The same department is also responsible for waste disposal from cesspits, septic tanks, pit latrines and the municipal wastewater treatment plant.

If adequate control of solid waste management is to be retained by these local governments, an enlargement and redistribution of responsibilities is required. Enactment and enforcement of regulations and standards are also necessary in order to protect the environment and public health. Figures 33 and 34 show the existing organization structure for Moshi and Arusha towns. Figure 35 shows a proposed organization structure for both towns.

The proposed organization structure does not include a planning unit. Planning can be carried out by the superintendents until the service is large enough to demand such a unit. Also the workshop can be under the works division in the near-term when refuse collection vehicles and equipment are few. The disposal section can be optional when crude open dumping is being practised, but it has to be established when a disposal facility like a landfill is developed.

For the refuse collection section, the foreman provides an upward mobility for the lower staff. The inspectors should know the standards and regulations because apart from providing a check on the work done by the foreman and the lower crew, they have to receive complaints and complements from citizens.



The number of zonal health officers and health assistants depends on the number of zones into which the town is divided. Moshi town is divided into four zones. For each truck there is one driver and six labourers.

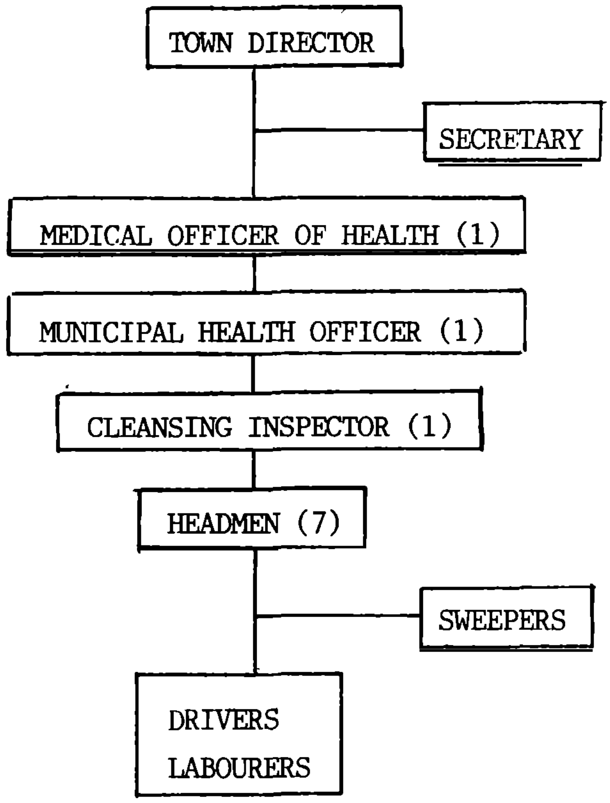


Figure 34. Organization structure for refuse collection in Arusha town.

Arusha town is also divided into collection areas and each area has a headman. Each collection vehicle has one driver and five labourers.

3) Finance

It is necessary to make financial arrangements to provide a steady and reliable source of money for operation and maintenance. This can be from the municipal budget as it is now or from user charges.

If a user charge is to be applied, the capital costs including amortization, operating and maintenance costs should be accurately calculated. These costs can then be related to electricity or water bills. A better breakdown will be required to differentiate domestic and non-domestic wastes.

Town Director

Secretary

CURATIVE SERVICES DIVISION
Medical Officer of Health

PREVENTIVE SERVICES DIVISION
Sanitary Engineer (1)

WORKS DIVISION
Town Engineer (1)

REFUSE COLLECTION SECTION
Superintendent (1)

NIGHT SOIL COLLECTION SECTION
Superintendent (1)

DISPOSAL SECTION
Superintendent (1)

Inspectors (2) | Clerks Typist

Inspectors (2) | Clerks Typist

Inspector (1) | Clerks Typist

Foremen (4 or 7)

Foremen (4 or 7)

Foremen (2)

Sweepers

Drivers
Collectors

Equipment
Operators
Labourers

Drivers
labourers

Workshop
Superintendent (1)

Foremen (2) | Inventory Clerks Typists

Mechanics

Figure 35. Proposed organization structure for refuse collection and disposal in Moshi and Arusha towns.

The number of foremen depends on the number of collection areas into which the town is subdivided.

Alternatively, standardised containers can be provided to each house. Depending on the number of tenants, a house can have more than one container. The days for collection by trucks are specified. Then each house owner has to pay for each container emptied. Standardized containers can be arranged by the local government and sold to house owners at a subsidised price. This will reduce the tendency for an individual to view the container in the next house as more valuable. These containers will be viable for high, medium and low density areas. For institutions, commercial areas and markets, big communal standardized bins can be provided. For market and commercial areas, the taxes can include the cost of waste collection. Institutions can be required to pay a monthly charge which shall be related to the number of containers collected. After some time, the average number of containers collected per month from a particular area will be known and even an average monthly bill can be calculated.

Periodical review of the generation rate should be made for each area annually. When this volume basis is used, heavy solid wastes like construction and demolition debris should be collected under special requests and special bills.

Table 26 shows a yearly comparison of the available refuse collection equipment.
Notes:

- The interest rate has been taken so as to march inflation rate for 1984 - 1985.
- Price of rear loader: Price in 1977 was available and has been multiplied by a suitable price index which is related to prices for other units in 1977 and 1985.
- Fringe benefits are expressed as a percentage of the total labour costs.
- Equipment maintenance includes fuel, tyres, oil and service.
- Trips per day are taken as average number of trips per day.
- Trailer capacity is taken as 5 m^3.
- Side loading truck capacity is taken as 12 m^3.
- Rear loader capacity is taken as 15 m^3.
- Loads per trip are based on density of 280 kg/m^3 for uncompacted refuse and 400 kg/m^3 for compacted refuse.
- Unit prices are for 1985 rates, and were obtained from K.J. Motors (a dealer of motor vehicles in Moshi town branch).
- Format has been obtained from Cointreau 1982.

Table 26. Yearly comparison of available refuse collection equipment per vehicle in Moshi and Arusha. 90 minutes round trip travel time.

	NON-COMPACTION					COMPACTION
	Tractor with open trailer		Tractor shuttle system with open trailers		Side loading truck	Rear loader
	Tractor	Trailer	Tractor	10 trailers		
ırchase price per ıit/system TAS	400 000	140 000	400 000	1 400 000	600 000	3 000 000
stimated life time	10 years	10 years	10 years	10 years	7 years	7 years
ınualised capital ost (purchase price 30 % interest over ife time)	129 385	45 285	129 385	452 850	214 125	1 070 620
abour including 7 % of fringes :iver 12 000 TAS abourer 10 000 TAS	(1) 14 040 (6) 70 200		(1) 14 040 (1) 11 700		(1) 14 040 (6) 70 200	(1) 14 040 (4) 46 800
ıel: gasoline 18 TAS/1, .esel à 10 TAS/1	52 500 (15 1/day)		52 500 (15 1/day)		126 000 (20 1/day)	126 000 (20 1/day)
ehicle maintenance) % of purchase price	80 000		80 000		150 000	600 000
:ailer maintenance 10 % of purchase price		14 000		140 000		

Table 26. Cont'd.

	NON-COMPACTION					COMPACTION
	Tractor with open trailer		Tractor shuttle system with open trailers		Side loading truck	Rear loader
	Tractor	Trailer	Tractor	10 trailers		
Management and administrative overhead (10 % of direct labour)	7 200		2 200		7 200	5 200
Miscellaneous fees including insurances	40 000	14 000	40 000	70 000	60 000	300 000
Total annualized cost	793 325	213 285	754 595	2 062 850	1 241 565	5 162 660
Total annualized system cost		1 006 610		2 817 445	1 241 565	5 162 660
Trips per day		3		10	3	3
Metric tons per load		1,4		1,4	3,4	6
Metric tons per year, trips/day x 350 days/year x metric tons per load		1 470		4 900	3 570	6 300
Cost per metric ton		684,75		575,00	347,80	819,45

It can be seen from the analysis that the side loading truck is the cheapest option. It is a viable selection as it is being practised.

If a solid waste generation rate of 0,5 kg/cap/day is considered, a person would be required to pay about 63,30 TAS per year or about 5,30 TAS per month for refuse collection. A normal family house can have up to 7 people, and therefore they have to pay 37,10 TAS per month. The water and electricity bills for the same family are on average 2 to 2,5 times higher each.

Figure 36 shows a schematic financial resource and budget planning system developed by David Jones and reported by Cointreau (1982).

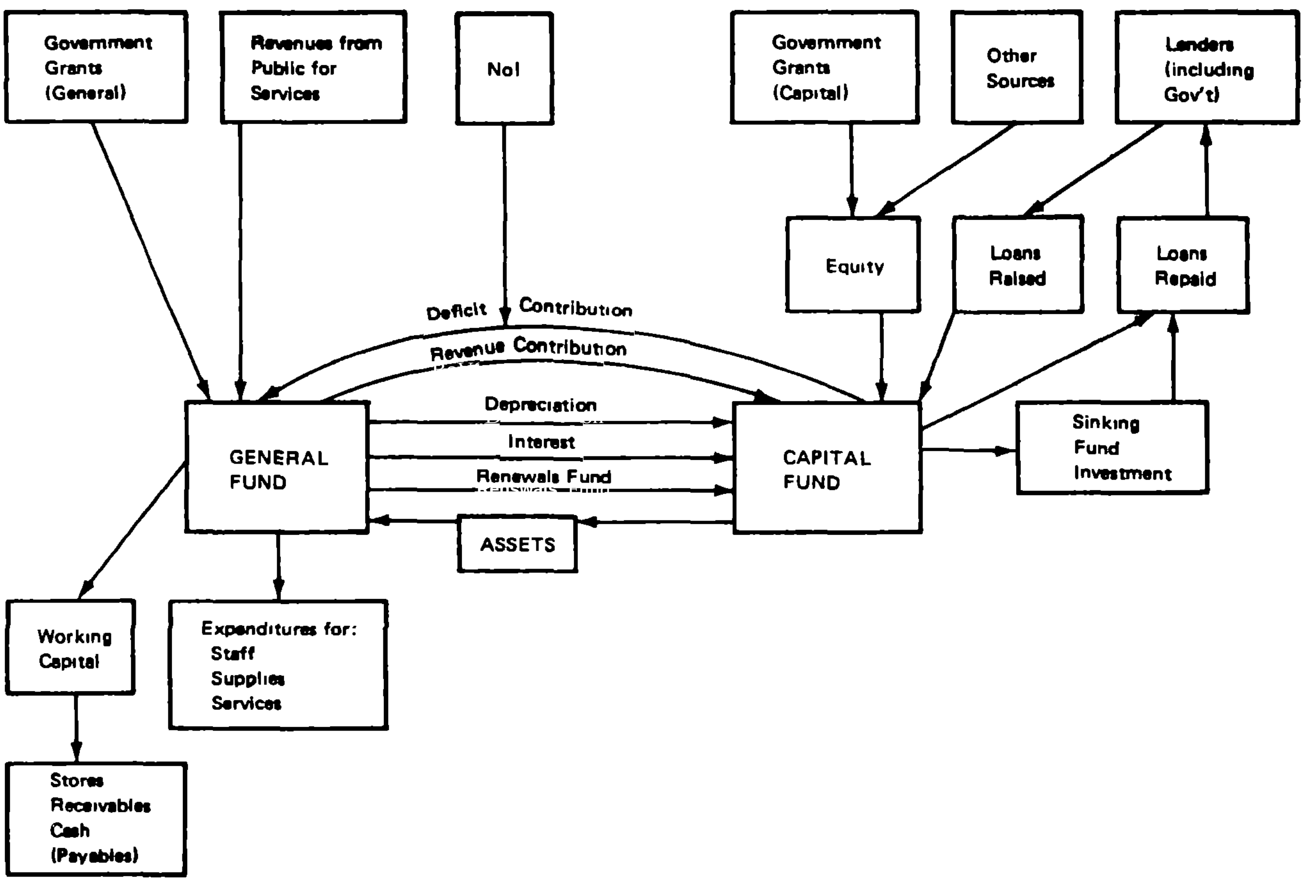


Figure 36. Schematic financial resource and budget planning system (Cointreau 1982).

6.2 Storage, collection and transportation

1) Storage

There are two types of storage: separate unit storage (household) and communal storage.

The separate unit storage can be non-standardized containers ranging from temporary containers such as cardboard cartons and crates to permanent containers such as plastic or metal bins. Standardized containers have a major disadvantage that they are relatively valuable, and therefore attractive to thieves.

Communal storage units can be either stationary or portable. Stationary units are such as four-sided masonry units with a door opening and without a roof. Portable units can be either large steel drums or other liftable metal containers. Stationary units are not recommended because (Cointreau 1982):

- wastes will be strewn about the site by various scavenging animals and people,
- people offended by the site will not walk to the opening to discharge their wastes,
- manual labour is required to remove the wastes,
- breeding of flies and other disease vectors is not limited.

Therefore for the individual houses in the low, medium and high density areas, the separate unit storage can be applied. It will be better if the collection vehicles pass a particular area on specific days, so that individuals who wish to keep their storage units in the backyard can do so, and take them out during the days specified for collection.

Squattered areas, institutional, commercial and market areas can be provided with large communal bins with lids. These should be placed strategically so that placement of refuse and collection by trucks is easy. The size should be such that they can accommodate adequate amounts of wastes which makes the collection efficient but does not allow the wastes to accumulate for prolonged periods of time. In some areas, collection can be even once a week, but some other areas like the market areas may demand a minimum of 2 to 3 times a week.

In estimating the storage capacity required for different areas, the following data can be used.

- Generation rate for existing serviced areas is 0,5 kg/cap/day.
- Per capita generation rate for squattered areas is 0,25 kg/cap/day.
- Increase in generation rate is 4 %.
- The density of collected waste is 330 kg/m^3 for Moshi and 275 kg/m^3 for Arusha town.

More knowledge will be gained as implementation proceeds and periodical reviews of the data are necessary. The generation rate observed in the field for Arusha town was lower than 0,5 kg/cap/day, and yet it has been proposed. This was attributed by shortage of fuel and therefore the level of service was lower than normally. Also Leaning (1977) proposed the same generation rate for Arusha town for the years 1982 - 1997. The increase is suggested by Leaning (1977).

2) Collection and transportation

Due to limitations in foreign exchange and level of technology, the truck system of collection and transportation is a viable option for Moshi and Arusha towns. The tractor and trailer shuttle system serving the market areas is also a good option when there are no large communal bins. The only issue is to select the best kind of trucks.

The self tipping non-compacting trucks are preferred to trucks without tipping gears in order to minimize unloading times. The trucks can be similar to the existing ones with the capacity of 12 m^3 and with covered platforms because local mechanics are more used to them. This kind of trucks would need about 5 to 6 people with a driver. The number of trucks required can be worked out after determining the level of service to be provided, the frequency of collection, and by using the data provided for generation rate and density of the refuse. An example for determining the number of trucks at any time for Arusha town is provided below.

Population	83 000 people
Level of service required	80 %
Frequency of collection	3 times a week

Generation rate	0,5 kg/cap/day
Refuse density	0,275 tons/m^3
Number of trips	2 trips per truck per working day

Therefore the weight produced per day is 83 000 x 0,5 = 41,5 tons/day.

The level of service required is 80 %, thus 33 tons per day should be collected. The density is 0,275 tons/m^3, and the volume to be collected is 120 m^3. The frequency of collection is 3 times a week, and therefore at days of collection 240 m^3 is needed to be collected. The capacity of a truck is 12 m^3 and it can take only about 80 % of the full capacity and make 2 trips in one day. Therefore each truck collects

12 x 0,8 x 2 = 19,2 m^3 per day.

The number of trucks required is

240 : 19,2 = 12,5 or 13 trucks.

If the collection is to be carried out daily, then 7 trucks are enough to provide the service. 50 % standby capacity is acceptable.

It should be noted that in the above example, the total population has been considered to generate 0,5 kg/cap/day. If 40 % of the total population live in squattered areas, then a generation rate of 0,25 kg/cap/day has to be considered for them.

It is necessary to provide specific crews to specific areas. Moshi and Arusha towns are segmented into collection areas which a vehicle can cover in a day. This concept should be retained. There are best routes within the collection area, but they are complex to determine. It would be a good idea if the operators of the vehicles are left to determine the best route. This will not only allow the operators some discretion and initiation in the routing but also encourages responsibility of providing good services to the residents (Leaning 1977).

To increase and enhance the collection practice, by-laws and controls must be established locally to be adhered and respected by all solid waste generators. Standardization of practices will sustain good habits which will facilitate collection, decrease potential health hazards and increase the aesthetic value of the towns. Fixing the collection days will increase the efficiency by allowing the citizens, commercial outlets and institutions best prepare for the collection day. Fixing the pick-up locations will also contribute to the collection efficiency. Bulky wastes, like big tree branches, are normally scavenged but in the case they need to be disposed, it should be done by a special request to the collection authority.

6.3 Disposal methods

The existing crude open dumping method is not an acceptable form of disposal. It is a potential health hazard to the community and a danger to the natural environment.

A number of feasible treatment and disposal systems exist including:

1) sanitary landfill,
2) incineration, with and without energy recovery,
3) materials recovery, and
4) composting.

Sanitary landfill is an economical and safe method of disposal for most wastes. It is technologically acceptable, safe and effective if good design and control is incorporated. This is recommended as a long term solution. However, good planning is required because from the cost figures showing the relative costs of different alternatives for waste disposal, landfilling is the cheapest. On the other hand, the cost of disposal per ton tends to be too high as the amount of solid waste to be disposed gets smaller.

Incineration is not a viable alternative because the operating costs are prohibitive.

Materials recovery requires wastes with high content of recoverable and saleable products which the wastes in these towns do not have.

Composting may need too high operation and maintenance costs which may counter act any benefits gained from its adoption (particularly when it is mechanized). However, individual household composting should be encouraged in the low density and squattered areas. Some people practise burning of refuse that have been collected in small pits or heaps. This should be encouraged in the low density and squattered areas but not in the centre of the towns. On road side burning should be discouraged. At the same time the local government can try some small scale manual composting for some of the domestic solid wastes. The economics of such a trial should be monitored periodically in order to establish facts on its adoption.

6.4 Disposal areas

For Moshi town, the existing open dumping site is not a convenient site for open dumping because the site is too close to the perennial Njoro stream which is put into many uses downstream. Some people use the water for domestic and agricultural purposes. The stream joins to other rivers downstream and enters the "Nyumba ya Mungu" reservoir (figure 37) where different activities take place (e.g. fishing, swimming, a source of domestic water supply).

Secondly, the site is quite rocky and irregularly sloping. This will demand expensive operations before a landfill can be developed there. An intensive geological survey is needed to identify fissures. Probably a clay barrier must be provided and importation of cover material is necessary because a trench method will not be feasible.

It is therefore proposed that the site can be used only in the near future. Effort should be made to identify another site which can be developed to a landfill. While the existing site is being used, there should be identified areas within the dump where wastes from different sources can be separately dumped. Refuse containing hospital wastes can be dumped on a specific area at the site which can be selected judiciously so that it can be burned if required and cannot be easily flushed away to the stream during heavy rains.

For Arusha town, the area is quite suitable for development of a sanitary landfill. The main issue is that the area is already an identified area for active land uses, and even construction of residential flats has cleared part of the dumping site. There is a proposal to shift it some 2 km further to the south. It is proposed that while progressing to the south, investigations must be made to establish the total usable land area and operational procedures to optimize its use. In the case resources allow the development of a sanitary landfill which is recommended, the area proposed by Leaning (1977) can be developed (appendix 2).

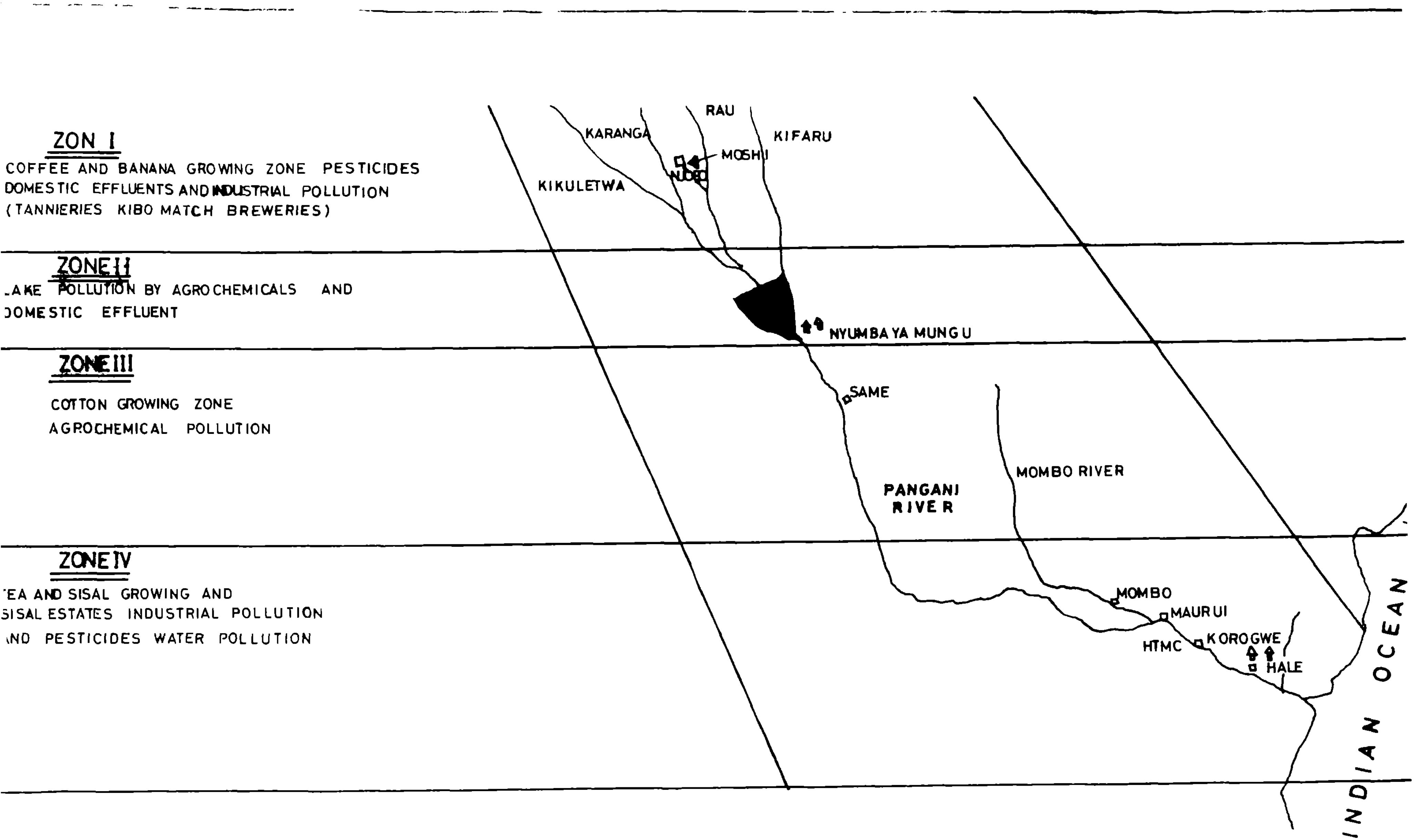


Figure 37. Lake and river pollution.

6.5 Training, education and participation programmes

Proper training and supervision of refuse workers is an important step in upgrading the refuse management system. Informing the public of such items as the schedule of collection, requirement for storage container placement and removal for pick-up and methods for making complaints about the service can help to improve the system (Cointreau 1982).

Clean-up campaigns for some events are also valuable. The authority can compile a leaflet about the refuse management system and include such information as what services are provided, how many workers there are, what is the annual budget, what improvements are planned, what is the organization of the system, how a resident can obtain information or provide comments about the system, what is expected from the residents as a part of the cooperative effort and what are the health benefits of a cleaner town. Violation notices should also be a part of the education (Cointreau 1982).

Carefoot and Gibson (1984) gave some steps to be followed in determining the training and development needs. In each step the questions What is it? Why is it needed? How is it done? must be answered carefully.

Step 1 Determine the training and development needs.

Step 2 Analyse the tasks.

Step 3 Select trainees.

Step 4 Select the type of training.

Step 5 Select the venue, instructors and dates.

Step 6 Determine the costs.

Step 7 Prepare the training and development plan.

7 CONCLUSION

There are different methods of solid waste disposal. A sanitary landfill is a good method of solid waste disposal if it is properly planned, designed and controlled. It is a utility to have as a long term solution to solid waste disposal if the environment is to be preserved. At this juncture, when resources are very limited, the burden of environmental degradation can be reduced by encouraging small scale practices like household manual composting and burning of refuse in squattered and low density areas where the service is not extended to.

Choosing better areas for solid waste disposal whereby a phased development of a landfill can follow with time will help to reduce the risk of pollution to the aquatic environment. Development of areas where special wastes can be disposed off will also help. For example, pathological wastes can be disposed in a specially selected area and burning is facilitated by periodical spreading of sawdust on the wastes.

The local government should spell out guidelines to industrial enterpreneurs producing special wastes on the way they should handle and dispose off their wastes in order to protect the environment.

Standardization is necessary particularly in storage and collection of solid wastes. Some by-laws have to be established and communicated to the general public to be honoured in order to minimize the nuisance caused by waste that is strewn around the non-standardized containers and on curbside of the streets.

The side loading non-compacting trucks with a covered platform and a tipping gear are a good selection for transportation of solid wastes to the disposal site. The generation rates, plans and actions need periodical reviews in order to make budget plans, collection and transportation requirements.

Although favoured, the compaction trucks are not cost effective because they are more expensive and the foreign exchange component is higher compared to the other trucks. Also the density of the wastes in these towns is high such that the compaction ratio that will be achieved will not exceed 1 : 1,5 to 1 : 2.

A system of cost recovery for service rendered should be tried in order to cover at least the local component of the costs for operation and maintenance of the solid waste management system.

Information to the general public on different elements of the solid waste management system is also necessary.

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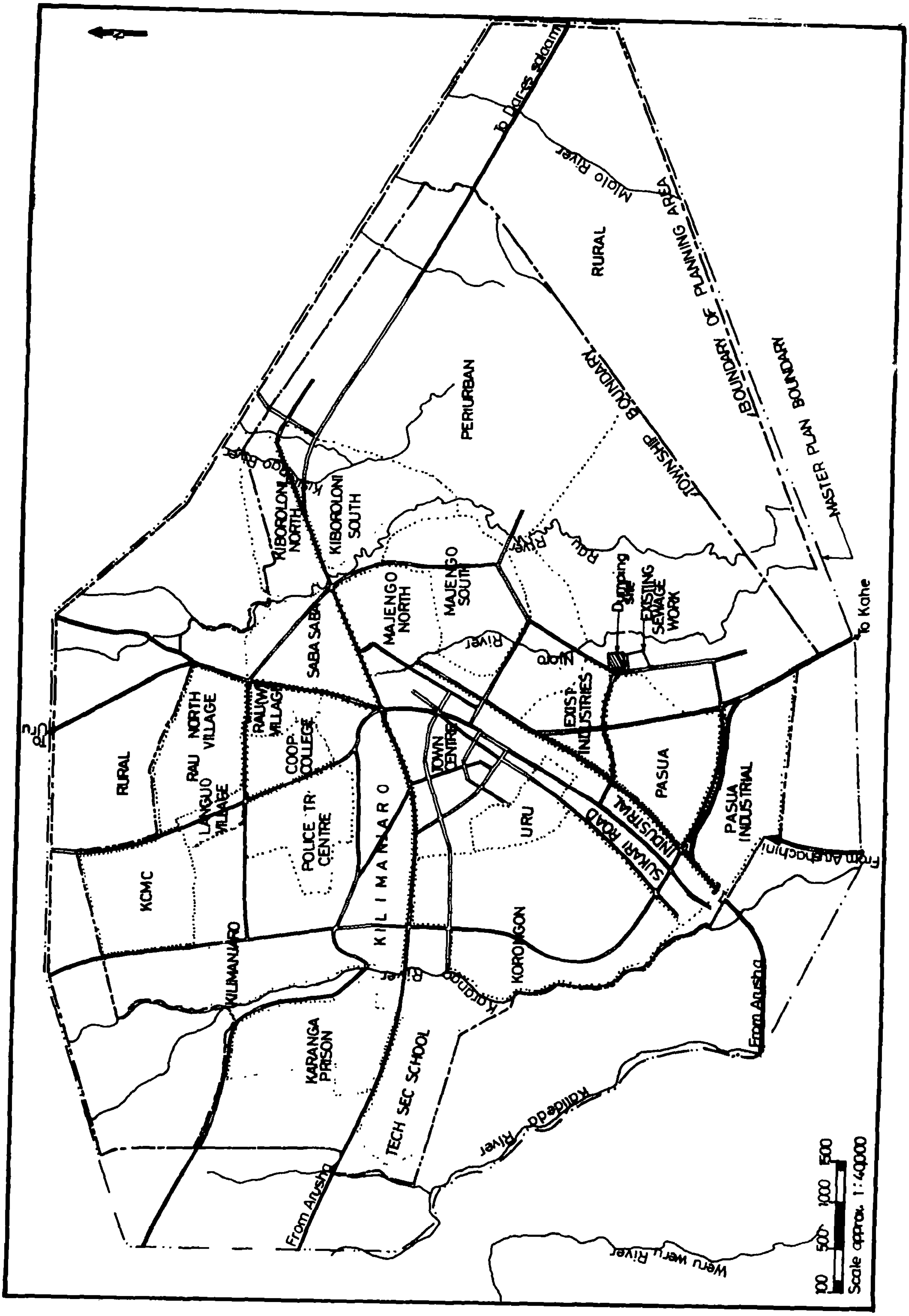
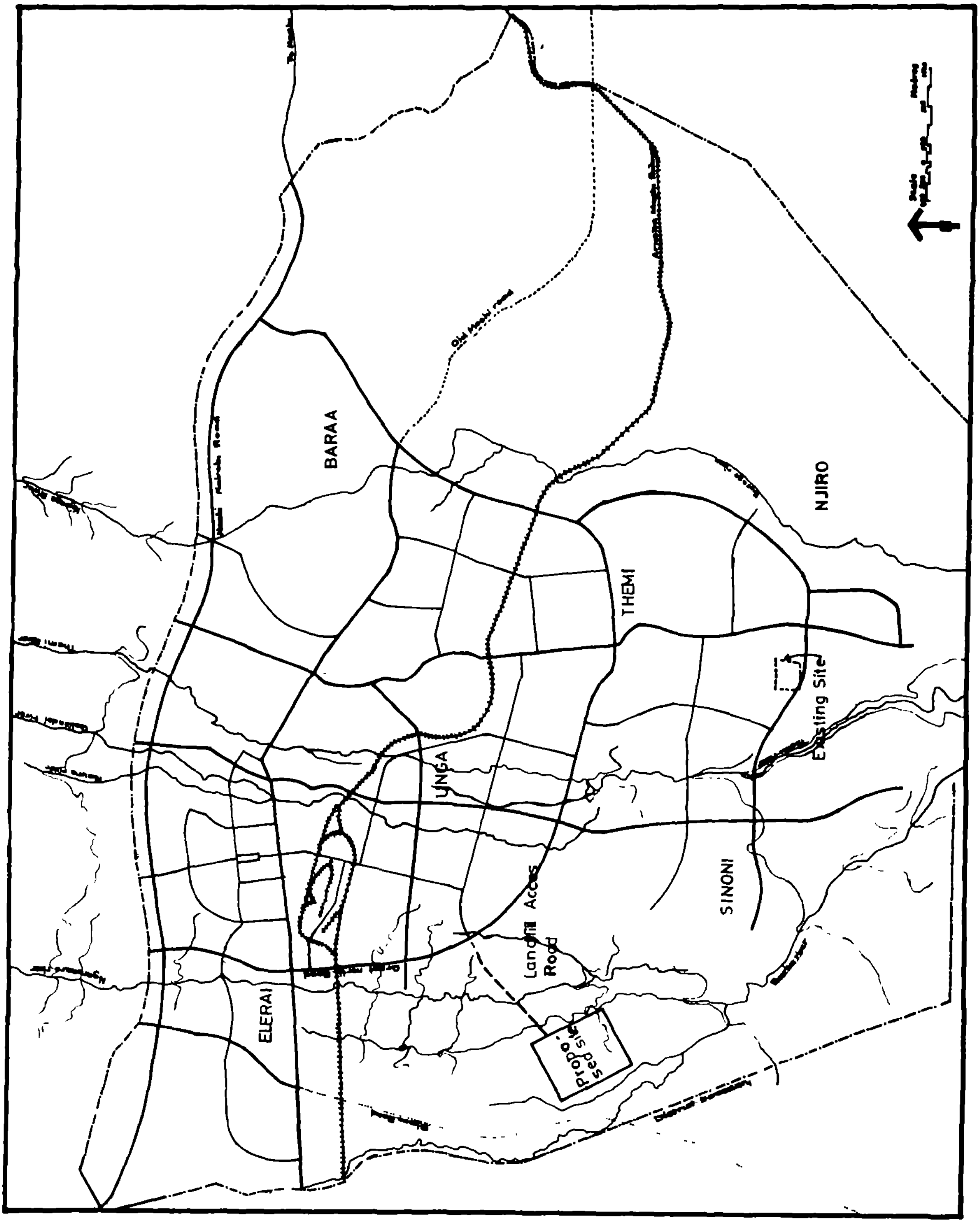
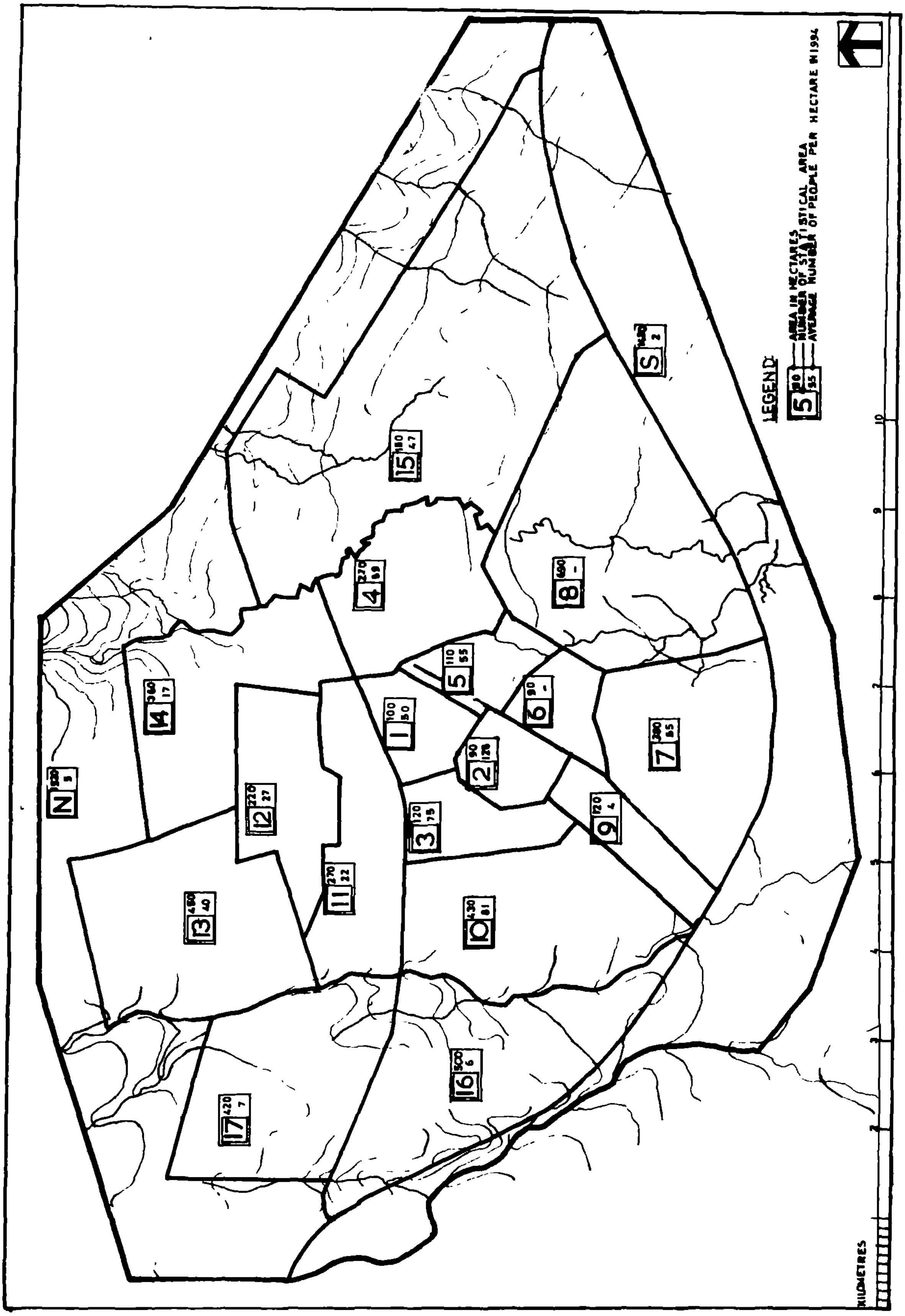

To Dar-es salaam
Mlalo River
RURAL
BOUNDARY OF PLANNING AREA
MASTER PLAN BOUNDARY
TOWNSHIP BOUNDARY
PERIURBAN
KIBOROLONI NORTH
KIBOROLONI SOUTH
MAJENGO NORTH
MAJENGO SOUTH
Rau River
Dumping site
EXISTING SEWAGE WORK
To Kahe
SABA SABA
Njoro River
EXIST. INDUSTRIES
PASUA
PASUA INDUSTRIAL
INDUSTRIAL ROAD
SUKARI ROAD
TOWN CENTRE
URU
RAU (W) VILLAGE
CO-OP. COLLEGE
RAU NORTH VILLAGE
RURAL
LANGUO VILLAGE
POLICE TR. CENTRE
KILIMANJARO
KCMC
KORONGON
Karanga River
KILIMANJARO
KARANGA PRISON
TECH SEC SCHOOL
From Arusha
From Arusha
Weru weru River
Scale approx. 1:40000
100 500 1000 500

ARUSHA TOWN (Leaning 1977)



MOSHI MASTER PLAN STATISTICAL AREAS (Hankkio and Berege 1974)



STANDARDS OF PHYSICAL AND CHEMICAL QUALITY OF POTABLE WATER (Gumbo 1984)

No.	Water classification and substances	Standards of water quality of different countries				
		Units	International		European	Tanzanian
			Acceptable	Allowable		
.	Water causing toxic effects	mg/1	n.m.	0,05	0,10	0,10
.1	Lead, Pb	mg/1	n.m.	0,05	0,05	0,05
.2	Arsenic, As	mg/1	n.m.	0,01	0,01	0,05
.3	Selenium, Se	mg/1	n.m.	0,01	0,01	0,05
.4	Chromium (b), Cr	mg/1	n.m.	0,05	0,05	0,20
.5	Cyanide, Cn	mg/1	n.m.	0,20	0,05	0,05
.6	Cadmium, Cd	mg/1	n.m.	0,01	0,01	0,05
.7	Barium, Ba	mg/1	n.m.	1,00	1,00	1,00
.8	Mercury, Hg	mg/1	n.m.	n.m.	n.m.	n.m.
.9	Silver, Ag	mg/1	n.m.	n.m.	n.m.	n.m.
2.	Water affecting human health					
2.1	Fluoride, F	mg/1	n.m.	1,5	0,7 - 1,7	8,0
2.2	Nitrate, NO_3	mg/1	n.m.	30,0	50/100	(100)
3.	Water for general domestic use					
3.1	Water being organol septic					
3.1.1	Colour	mg Pt/1	5	50	n.m.	50
3.1.2	Turbidity	mg SiO_2/1	5	25	n.m.	30
3.1.3	Taste	-	n.o.	n.m.	n.m.	n.o.
3.1.4	Odour	-	n.o.	n.o.	n.o.	n.o.

APPENDIX 4
Cont'd

STANDARDS OF PHYSICAL AND CHEMICAL QUALITY OF POTABLE WATER (Gumbo 1984)

No.	Water classification and substances	Standards of water quality of different countries				
		Units	International		European	Tanzanian
			Acceptable	Allowable		
3.2	Water of salinity and hardness					
3.2.1	pH	-	7,0 - 8,5	6,5 - 9,2	n.m.	6,5 - 9,2
3.2.2	Total filtrable residue	mg/1	500	1500	n.m.	2000
3.2.3	Total hardness	mg $CaCO_2$/1	n.m.	n.m.	500	600
3.2.4	Calcium, Ca	mg/1	75	200	n.m.	n.m.
3.2.5	Magnesium, Mg	mg/1	50	150	125	n.m.
3.2.6	Magnesium-sodium sulphate	mg/1	500	1000	n.m.	n.m.
3.2.7	Sulphate, SO_4	mg/1	200	400	250	600
3.2.8	Chloride, Cl	mg/1	200	600	600	800
3.3	Water with non-toxic metals					
3.3.1	Iron, Fe	mg/1	0,3	1,0	1,0	1,0
3.3.2	Manganese, Mn	mg/1	0,1	0,5	0,05	0,5
3.3.3	Copper, Cu	mg/1	1,0	1,5	0,05/3,00	3,0
3.3.4	Zinc, Zn	mg/1	5,0	5,0	5,0	15,0
3.4	Water with organic pollution of natural					
3.4.1	BOD_5	mg O_2/1	n.m.	6,0	n.m.	6,0
3.4.2	PV (oxygen abs. $KMnO_4$)	mg O_2/1	n.m.	10,0	n.m.	20,0
3.4.3	Ammonium, NH	mg/1	n.m.	0,5	0,05	1,0
3.4.4	Total nitrogen, exclusive nitrate	mg/1	n.m.	0,1	n.m.	1,0

STANDARDS OF PHYSICAL AND CHEMICAL QUALITY OF POTABLE WATER (Gumbo 1984)

No.	Water classification and substances	Standards of water quality of different countries				
		Units	International		European	Tanzanian
			Acceptable	Allowable		
3.5	Water with organic pollution introduced artificially					
3.5.1	Surfactants ABS	mg/1	0,5	1,0	n.m.	2,0
3.5.2	Organic matter as carbon in chloroform extract	mg/1	0,2	0,5	0,5	0,5
3.5.3	Phenolic substance as phenol	mg/1	0,01	0,002	0,001	0,002

Annotations: n.m. = not mentioned
n.o. = unobjectionable