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**the improvement of
domestic sanitation in
unsewered areas of kenya**

1. INTRODUCTION

The intention of this paper is to describe the problems which arise when providing domestic sanitation in unsewered areas and to show how one country, Kenya, is attempting to overcome these difficulties.

The selection of Kenya as an example is solely because the author has recent experience of this country's problems and their solution. Similar situations - indeed often much worse situations - may in the author's experience be found in virtually every country of the world.

Kenya is, in fact, to be congratulated because its Government realises the advantages of proper sanitation and is actively taking steps to overcome its present problems. The initial step was to take advice from the World Health Organization.

The benefits of proper sanitation are well known and are here summarised only to set the following technical discussion into perspective:

- The reduction of hazards to human health
- The prevention of unacceptable or uneconomic pollution of water resources
- The elimination of aesthetic nuisance
- Improved convenience.

Kenya has the common problems of a rapidly increasing population, especially in urban communities, rapidly advancing industrialisation and rising living standards.

The Kenya Government is attempting to keep pace with these changes and in the sanitation field has the objective of ensuring that every dwelling and every business and factory in the country will have adequate sewage disposal arrangements by the end of this century.

TABLE 1: Summary of domestic sewage disposal methods anticipated in Kenya, outside Nairobi, by the year 2000

Type of Community or area	Anticipated Sewage Disposal Method (thousands of persons)								Projected population for year 2000 (thousands)
	Sewerage	Septic tanks	Large (1) cesspools	Small * cesspools	Aqua-privies	Pit latrines	Bucket lavatories	None	
Nomadic	-	-	-	-	-	300	-	700	1000
Low potential rural	-	60	-	-	60	2010	60	110	2300
Medium & high potential rural	20	730	40	350	-	12 560	-	-	13 700
Low density urban	350	360	30	150	170	440	-	-	1500
High density urban	5700	180	60	-	60	-	-	-	6000
Totals	6070	1330	130	500	290	15 310	60	810	24 500

(1) That is, dealing with water-borne sanitation

* That is, not dealing with water-borne sanitation

The sub-objectives of this programme are:

- The provision of sewerage in more intensely populated urban areas (including all those with more than 124 persons per hectare).
- Every sewage disposal installation constructed in the future shall be appropriate to the circumstances and properly designed and constructed.
- Every sewage disposal installation in Kenya shall be effectively used, operated, maintained and serviced.

It may appear that the first of these sub-objectives will eliminate Kenya's domestic sanitation problems, but this is not the case. Table 1 shows that even with the intensive sewerage capital development programme - estimated to cost Kenyan £212 million (approximately £300 million sterling) at 1972 prices - needed to achieve this sub-objective by the year 2000, the overwhelming majority of Kenya's citizens will still be served by individual-type domestic sanitary installations.

This is the justification for paying increasing attention to the choosing, design, construction and servicing of such facilities, and for this Paper.

2. BACKGROUND TO MY INVOLVEMENT

An agreement for the development of rural water supplies in Kenya, signed in 1970 by the Swedish and Kenya Governments, contained the requirement that the Kenya Government should establish long-term national plans for water supply development.

Discussions concerning this plan demonstrated the need for a national study into the Kenya Water Sector; the World Health Organisation (WHO) was chosen as the executing agency. The review and national planning of sewage disposal, plus the preparation of national guidelines and design criteria, were included in the study.

Field operations commenced in 1971. The study was essentially a co-operative effort between WHO and the Water Department of the Kenya Government. WHO provided a team of nine experts, who worked in Kenya for varying periods. The Kenya Government provided experts and support staff, to bring the total input to 500 man-months of which the WHO input was one-third.

A total of seventeen reports were issued by the study team. I had the honour of being the WHO Sanitary Engineer responsible for the sewage disposal reports.

The study ended in 1973. I had the privilege of being invited back to Kenya as Project Manager on the second or implementation phase. Specifically, my task was to implement the recommendations in the sewage disposal reports which included establishing the first Kenyan national sewerage agency. This became a division within the Water Department of the newly-formed Ministry of Water Development.

I spent the next two and a half years as a WHO staff member heading the Sewerage Division in the Kenya Government. During this time the Sewerage Division grew in numbers and prestige and was able to initiate a national sewerage development programme, sewerage training courses for sub-professional Government personnel, plus several more of the report recommendations.

It was an interesting and exciting period of my career. The material in this Paper is in part abstracted from the WHO sewage disposal reports, and is partly based upon my subsequent experience.

3. METHODS CURRENTLY USED IN KENYA

It is not intended in this section to give comprehensive descriptions or design details of the various methods of domestic sanitation. To do this would obscure the primary purpose of this Paper. The brief descriptions which are given should be regarded rather as definitions abstracted from a glossary.

Also, with the aim of simplicity, no attempt has been made to discuss the relative merits of the variety of improvements and inventions now available which go to improve the efficiencies of the various methods. For example, in recent years excellent techniques for improving the water seal on aqua-privies have been developed.

This paper instead deals with the basic form of each, on the assumption that the most suitable variations will be taken into account and adopted when preparing standard designs (see section 5).

Summary of the situation

In 1972 the total population of Kenya was approximately 12 millions, of whom perhaps five percent lived in Nairobi. Of those living outside Nairobi, only 0.9 millions lived under urban conditions, leaving a balance of 10.5 million rural dwellers.

The types of villages which occur in Europe are unusual in Kenya; here the rural population tends to live on scattered smallholdings or farms, grouped generally around market and local centres, and the towns and cities.

The WHO study carried out during that year revealed that, outside Nairobi, the types of domestic sewage disposal facilities were divided approximately as follows:

- Primitive sanitation - 51% of the population
- Conservancy systems (bucket latrines or cesspools) - 3%
- Pit latrines - 40%
- Septic tanks or aqua-privies - 4%
- Sewerage - 2%

This tends to give an optimistic picture of the situation, as many of the installations were found to be inefficient and were health hazards. This was often because they had been poorly designed or in the case of septic tanks, aqua-privies and pit latrines, because they had been constructed in unsuitable ground. However, the great majority of troubles and difficulties resulted from bad maintenance and poor servicing.

Primitive methods

This term is here used to cover the variety of simple waste disposal methods ranging from indiscriminate urination, defaecation and sullage disposal to hygienic waste burial.

Direct excretion on to the ground surface is inexcusable in any type of community. It is perhaps acceptable for persons travelling or living alone in remote areas, provided some discretion is exercised.

Indiscriminate excretion on the ground surface or, even worse, into watercourses, is no doubt the reason for the prevalence in Kenya of disease, including bilharzia (schistosomiasis) which is present in most streams and rivers. Particularly dangerous is the nomads' habit of excreting close to the unprotected wells found in the arid regions.

Burying excreta, if carried out quickly and conscientiously, is satisfactory for communities in sparsely-populated areas. Either a shallow trench latrine, into which a layer of soil is added after defaecation, or a soil box, the contents of which are regularly emptied, are satisfactory.

Unhappily, the regular burial of wastes requires a measure of discipline and so unless there are servants to do this work, or there is an overall discipline as in a military camp, burial systems cannot normally be relied upon to continue.

The indiscriminate disposal of sullage, which is water dirtied as a result of domestic washing or food preparation, is normally not so dangerous to health, provided that the population density is not high, the ground on which the sullage discharges is permeable and there is no danger of it polluting water supply sources.

Where quantities of sullage are small, and buildings not too close to each other, throwing a bucket of dirty water on to the ground causes little trouble; a combination of soakage and evaporation soon eliminates the pool.

If rather more sullage is discharged from a sink drain than where plots are large, a simple system of shallow ditches will often suffice and will help irrigate crops. However, this method often provides conditions suitable for insects and vermin, and can be a health risk and cause nuisance. It should be remembered that sullage can contain a wide range of unpleasant suspended matter which can decompose anaerobically, in addition to grease which clogs the ground.

It is never satisfactory to discharge sullage on areas where it will pond, or into shallow open drains which often merely transport the resulting health hazard to another location. However, this rule is rarely obeyed with the result that pools of water or patches of damp ground are always apparent in populated areas in Kenya, even during the dry seasons of the year.

Conservancy - bucket latrines

Bucket latrines should comprise leak-proof containers which are frequently emptied before they become full. The buckets are usually small, and normally deal with excreta only.

Even at their best bucket latrines have very few merits unless expensive sterilising chemicals are regularly added to their contents; this is rarely the case in a country such as Kenya.

The more usual picture of a bucket latrine is of an unhygienic and offensive facility, nearly always leaking or overflowing and usually surrounded by vermin and insects, many being of the types which help spread human diseases. Sometimes a degree of cleanliness is achieved in Kenya by keeping poultry which devour insects. The need to install bucket latrines in a simple shed, from which they may be quickly removed, frequently means that they are at all times visible to the passers-by.

At the very least, each time they are emptied the buckets should be properly washed and disinfected, unhappily a rare occurrence as the servicing then changes in degree from simple bucket-emptying to carting away full buckets to a central cleaning depot.

The operation of collecting and disposing of nightsoil from bucket latrines is usually nauseating. In some Kenyan towns the buckets are manually carried long distances to the disposal ground. Except in the cities and large towns, a common method is to empty the buckets into handcarts, each comprising an empty drum supported horizontally across two wheels; when full the handcarts are dragged away to be tipped and emptied into a sewer, septic tank or local depression. Only rarely are the buckets and handcarts washed after use; spillage of nightsoil is frequent and health hazards are alarmingly obvious.

The installation of a bucket latrine does not solve the problem of disposing of sullage and where the ground is unsuitable this normally adds to the unhygienic conditions.

Pit latrines

Pit latrines are intended to deal only with excreta and should not receive sullage. If they do, rapid clogging of the wall surfaces and surrounding ground is liable to occur; flooding during wet weather can have similar effects.

Pit latrines are by far the most common type of constructed domestic sewage disposal facility in Kenya. Although there are communal pit latrines, most are private, serving only one family.

Where the ground is permeable and the water table low, pit latrines can operate well; however, care must be taken to ensure that seepage from a latrine cannot pollute underground water extracted from adjacent shallow wells. This danger is often overlooked.

When a pit latrine becomes full it should be covered by soil and replaced by a newly-dug pit. This requirement alone normally rules out a pit latrine as a method suitable for an urban environment where undeveloped land is scarce. This unsuitability is reinforced by the desirability of locating a pit latrine, which must always be regarded as a potential danger to health, at least ten metres from any dwelling or food storage and preparation area. This requirement is not always appreciated and a great number of pit latrines are improperly located too close to and even occasionally inside dwellings.

Pit latrines are frequently excavated in poor ground without sufficient internal support so that ground collapses become a constant nuisance and threat. Pit latrines are not suitable where the ground is impermeable or waterlogged. In such circumstances they fill rapidly. Although theoretically this problem could be overcome by frequent replacement by new pits, in practice pit latrines in such circumstances almost invariably overflow and spread diseases, especially hookworm.

Emptying of pit latrines should never be sanctioned, although this is a far from uncommon practice. The need to empty a pit latrine is a clear indication that this method of sanitation is unsuited to the circumstances. A generous description of such pits is that they are sub-standard open cesspools with difficult access for emptying.

Emptying of pit latrines does occur, usually manually - a dreadful task. This produces the problem of disposing of the pit contents, which in practice is frequently on to the nearest undeveloped site.

In hot districts pit latrines tend to smell and attract insects. These two problems can be controlled if the latrine slab is regularly cleaned and disinfected - a difficult task if the slab is not of concrete. In the past some local authorities in Kenya have very commendably supplied concrete pit latrine slabs to private individuals at nominal prices. However, the majority of pit latrine covers in this country are still of timber.

Where pit latrines are used there is normally the additional problem of how to dispose of sullage. The better method in permeable ground is to construct, as it were, a second pit latrine but filled with rubble and then covered to act as a soakage pit for the sullage. In particularly good ground rubble-filled covered trenches are equally suitable. Both these methods of sullage disposal are rare in Kenya today.

Aqua-privies

An aqua-privy can be considered to be a cross between a pit latrine and a septic tank, the tank being substituted for the pit. The watertight septic tank has a high outlet which allows the more liquid contents of the tank to overflow into a sub-surface ground soakage system. The normal arrangement on the relatively few aqua-privies found in Kenya is for the cover slab to have a simple squatting hole formed around a vertical pipe which extends below the surface of the liquid in the tank.

An aqua-privy is hygienically preferable to a pit latrine, provided that the ground is sufficiently permeable to absorb the overflow and the water seal is maintained by the frequent addition of water. For this latter reason aqua-privies have generally proved more satisfactory in Moslem areas as it is the admirable custom of these peoples to wash their bodies after using the toilet; the water thus used is sufficient to maintain the water seal.

Aqua-privies need de-sludging but only at infrequent intervals. However, as they are normally provided for low cost housing in smaller towns, the relatively limited servicing they require is usually ignored. The result is that in time most aqua-privy installations provided in Kenya have become entirely clogged by semi-dried sludge, which can only be removed by manual excavation.

Conservancy cesspools

Cesspools essentially are watertight sewage storage tanks; for hygienic operation they must be sufficiently large to hold all the sewage produced between emptyings, with sufficient spare capacity to allow for

additional inflows due to visitors or arising from breakdowns in emptying arrangements. Provided that cesspools are carefully and inoffensively emptied at frequent regular intervals they are both sanitary and satisfactory.

However, cesspools are expensive, especially where the water supply is piped so that water usage is high and the cesspools must therefore be large.

Cesspools are used where ground soakage is not possible. This could be because the ground is impermeable or waterlogged, or because a high density of development allows no spare ground for soakage systems. If these conditions do not exist then the much cheaper septic tank, with its considerably reduced servicing requirements, is a more suitable facility.

There are very few properly designed and constructed cesspools in Kenya. There are many sub-standard installations, however, plus a large number of pit latrines and septic tanks provided in unsuitable circumstances which inadvertently act as cesspools. The most common fault is that the cesspools provided are too small so that they overflow instead of storing all the sewage they receive. Often the overflow is through a pipe or hole deliberately left in the side of the cesspool by the builder. The overflowing sewage pollutes ground surfaces and water resources and this defeats the initial object of attempting to provide a sanitary installation.

The frequent and regular servicing of cesspools is a major problem in Kenya at the present time except in a few larger towns and cities. Because of the relatively large volumes of sewage involved, emptying is a task which can feasibly be carried out only by the use of cesspool-emptying vehicles, the operation of which demands a relatively high level of organisation and sophistication, and funds. Also there must be suitable discharge and disposal arrangements for the collected contents, preferably at a sewage treatment works designed for this task. In many districts in Kenya cesspools are emptied by means of hand buckets, a most distasteful and dangerously unhygienic method; transport of the contents is often by offensive open ox-carts; spillage is inevitable.

The cesspool will always have applications in Kenya. However, sewerage is an alternative which is so very much better and normally cheaper than a series of cesspools for urban areas.

Septic tanks

The septic tank is a watertight container with a high outlet which discharges sewage after settlement into a sub-surface soakage system, or occasionally to a further treatment unit. Treatment of septic tank effluent is only feasible on a communal scale and as this arrangement is thus more correctly classified under 'sewerage', it will not be discussed further in this Paper.

Where ground soakage is possible and permissible a septic tank can be an excellent method of disposing of all the sewage from a household. However, in congested areas or under impermeable, waterlogged or other ground conditions where soakage is impossible, a septic tank becomes merely an overflowing undersized cesspool. Septic tanks in Kenya have in many cases been constructed where the ground is unsuitable. Most of these have either natural or purpose-made, but nevertheless illegal, overflows into a convenient ditch or low-lying area.

For correct functioning the capacity of a septic tank is proportional to the daily sewage inflow and so capital costs can be reduced by disposing of sullage elsewhere; however, where the sullage has a high solids or grease content, as from high class housing, this is very often a false

economy because the sillage will quickly block any ground soakage arrangement if it does not first pass through a septic tank.

In Kenya septic tanks provided are often poorly designed or too small. A properly designed tank is relatively large and intricate and there is a great temptation for builders to cut costs. If a septic tank is too small then solids are carried over in the effluent to block the ground soakage arrangements. In the extreme the tank may be relatively so small that scour prevents the settlement of any sludge, and the installation does not function.

Occasionally, but regularly, accumulated sludge needs to be removed from a septic tank. A septic tank is thus dependent upon proper servicing which is often lacking in Kenya. It is common practice to delay emptying a septic tank until sludge accumulation causes blockages. If sludge is not emptied from a septic tank it will accumulate until it is carried over in the effluent. This sludge will quickly block any ground soakage arrangements, thus converting the septic tank plus its soakage system effectively into a cesspool. Ground soakage systems for septic tanks in Kenya are of two general types. Although the usual arrangement is to have open-jointed pipes laid along a rubble-filled trench, soakage pits are also common. These resemble pit latrines; they are usually hollow and covered by a slab containing a manhole cover for access.

When sludge carried over from a septic tank blocks a soakage trench the usual remedy is to extend the trench or to build more trenches in parallel. When the walls of a soakage pit become blocked, either more pits are constructed in series or frequently the walls of the blocked soakage pit are manually scraped to remove the deposited sludge which is causing the trouble. Sadly it is thus usually the symptom resulting from poor servicing which is dealt with rather than the lack of servicing which is the cause of the trouble. The extension of soakage trenches and the scraping of soakage pits has in Kenya tended to become the accepted method of servicing a septic tank.

By far the best method of de-sludging a septic tank is by means of a cesspool-emptying vehicle, but in Kenya these are owned by only the largest towns and cities. In other districts small wheeled tanks fitted with handpumps for raising the sludge into the tank are used. Poorer communities empty septic tanks by means of buckets. This means often that the sludge is merely dumped on the ground surrounding the tank. At the best, when emptying is manual, the sludge is taken away in open ox-carts.

The supervision and servicing of sanitary installations

The reasons why so many installations in Kenya produce disappointing sanitary results may be summarised as being because a high proportion are inappropriate to the circumstances, a large number of those which are properly chosen and planned are badly sized, designed and/or constructed, and few are properly serviced and maintained. Supervision by competent trained personnel is the only solution to the incorrect choice, design and construction of facilities.

Bucket latrines, aqua-privies, cesspools and septic tanks all need regular and efficient servicing. The organisation of such servicing is beyond the scope of individuals and in an advanced society must be considered the responsibility of the local public authority.

There appears to be an almost universal opinion amongst lay persons that once funds have been allocated and spent to provide an installation than financially that is the end of the matter. This opinion is not confined to domestic sanitation or even to community sewerage. As a result, time and again public authorities controlled by lay persons completely underestimate the manpower and financial requirements of servicing and

maintenance. The smaller town, urban and rural councils of Kenya have in the past fallen into this trap, with the result that most have found they are unable to service regularly and properly the domestic sanitary installations they have correctly insisted upon and approved.

4. COMPARISONS BETWEEN DOMESTIC SANITARY ARRANGEMENTS

An immediate difficulty is that the different methods do not all perform the same function, as the following examples show:

- i) Septic tanks followed by efficient ground soakage can effectively dispose of all the sewage - that is excreta plus sullage - from a household, producing only a relatively small volume of sludge in the process.
- ii) The two conservancy systems, i.e. bucket latrines and cesspools, merely store sewage pending its periodic removal and disposal collectively with the sewage of others in the community. Thus these are not truly methods of domestic sewage disposal.
- iii) Bucket latrines and pit latrines deal only with excreta and not with sullage.
- iv) Cesspools and septic tanks are the only individual-type arrangements which can deal with waterborne sanitation i.e. the drainage from water closets.

For this reason the following comparisons are not strictly valid. However, they are considered to be sufficiently accurate to produce meaningful conclusions.

Technical comparisons

Regardless of the sanitary arrangement adopted, the owner usually has a choice, unless the local authority dictates otherwise, as to how he disposes of sullage. For example, if the installation is a septic tank he could discharge his sullage directly on to the ground, into a sub-surface soakage system or through the septic tank. The total capital cost of the septic tank installation obviously varies with his choice.

Taking into account these alternatives, the various possible methods are listed and described in Table 2 'Sewerage', which in this Paper implies a sewer system plus all plant for pumping and treating sewage before disposal, is included for purposes of comparison.

TABLE 2: Various methods of domestic sanitation

(note: This table also serves as a key to Tables 3, 5 and 6)

<u>ABBREVIATION</u>	<u>DESCRIPTION</u>
LAND	Excretion directly on to the land surface.
BURY	Excreta buried; sullage discharged on ground.
BUCKET-G	Conservancy-bucket latrines; sullage discharged on ground.
BUCKET-S	Conservancy-bucket latrines; sullage disposal through sub-surface drains or soakage pits.
PIT-G	Pit latrine; sullage discharged on ground.
PIT-S	Pit latrine; sullage disposal through sub-surface soakage system.

AQUA PRIVY-G	Aqua-privy; sullage discharged on ground.
AQUA PRIVY-S	Aqua-privy; sullage disposal through sub-surface soakage system.
AQUA PRIVY	Aqua-privy; sullage discharged into privy.
CESSPOOL-G	Conservancy-cesspool; sullage discharged on ground.
CESSPOOL-S	Conservancy-cesspool; sullage disposal through sub-surface soakage system.
CESSPOOL	Conservancy-cesspool; sullage discharged into cesspool.
SEPTIC TANK-G	Septic tank; sullage discharged on ground.
SEPTIC TANK-S	Septic tank; sullage disposal through sub-surface soakage system.
SEPTIC TANK	Septic tank; sullage discharged to septic tank.
SEWERAGE	Public sewers connected to sewage treatment works; sullage discharged into sewers.

TABLE 3: Advantages and disadvantages of various methods of domestic sanitation.

SEWAGE DISPOSAL SYSTEM	Hygienic to use	Convenient to use	Public health hazard	Aesthetically satisfactory	Public nuisance	Suitable in impermeable ground	Unlikely to contaminate ground surface	Unlikely to contaminate underground drinking water	Unlikely to pollute surface water resources	Low capital cost	Cheap and easy to maintain	Maintenance is inoffensive	Public health risk if unit is not emptied regularly
LAND BURY	+++	++++	+	+	+	+++	+	++	+++				
BUCKET-G	+	++++	+	+	+	++	++	+++	+++	+++	+++	+++	+
BUCKET-S	+	++++	+	+	+	++	++	+++	+++	+++	+++	+++	+
PIT-G	+++	++++	+++	++	++	++	++	++	+++	+++	+++	+++	++
PIT-S	+++	++++	+++	+++	+++	++	+++	++	+++	+++	+++	+++	++
AQUA PRIVY-G	+++	+++	+++	+++	+++	++	+++	++	+++	+++	+++	+++	+++
AQUA PRIVY-S	+++	+++	++++	++++	++++	+	++++	++	++++	+++	+++	+++	+++
AQUA PRIVY	+++	++++	++++	++++	++++	+	++++	++	++++	++	+++	+++	++++
*CESSPOOL-G	++++	++++	+++	+++	+++	++	++	+++	+++	++	++	+++	+
*CESSPOOL-S	++++	++++	++++	++++	++++	++	++++	+++	++++	+	++	+++	+
*CESSPOOL	++++	++++	++++	++++	++++	++++	++++	++++	++++	+	+	+++	+
*SEPTIC TANK-G	++++	++++	+++	+++	+++	++	+++	++	+++	+++	+++	+++	+++
*SEPTIC TANK-S	++++	++++	++++	++++	++++	++	+++	++	+++	+++	+++	+++	+++
*SEPTIC TANK	++++	++++	++++	++++	++++	+	++++	++	++++	++	+++	+++	+++
*SEWERAGE	++++	++++	++++	++++	++++	++++	++++	++++	++++	++	+++	++++	+++

NOTES: The more plus signs the better.
 *It is assumed that water closets are connected to these units.

The technical advantages and disadvantages of the various methods are summarised on Table 3.

Cost estimates

Records of unit costs for domestic sanitary facilities are not systematically recorded in Kenya. Appendix B gives the bases for the estimates given in this section. The calculations leading to these cost estimates are detailed in Appendix A. Even where records do exist it is difficult to determine typical unit costs for any method; costs vary, for example, with the location, with the ease of excavation of the ground and with the sophistication of the building provided over a pit latrine or aqua-privy. Sewerage costs have even more variables. Inter alia, they depend upon ground conditions, topography and population density. For these reasons the estimated average unit costs which follow, although they are considered to be generally applicable throughout Kenya outside Nairobi, do not necessarily apply to any particular project in any particular location.

The estimated capital and running unit costs together with the anticipated working lives of the various sewage disposal installations listed are summarised on Table 4. This table has been based on an assumed average number of five persons per household or per latrine unit, except in the case of pit latrines where a figure of eight persons has been used.

TABLE 4: Approximate unit capital and running costs of various methods of domestic sewage disposal

Method	Capital cost	Life of unit in years	Annual running costs
BUCKET LATRINE	16	0.5	114
PIT LATRINE	60	8	24
AQUA PRIVY Tank	320	15)	64
Soakage arrangement	120)	
CESSPOOL	4800	20	268
SEPTIC TANK Tank	1600	20)	16
Soakage arrangement	300)	
SEWERAGE with conventional treatment			
(i) Sewers	800	40	16
(ii) Treatment	800	25	60
SEWERAGE with oxidation ponds			
(i) Sewers	800	40	16
(ii) Treatment	240	30	12

Notes: (next page)

- Notes:
- (i) All costs are based upon 1977 values.
 - (ii) All costs are given in Kenyan shillings (£1 sterling currently equals approximately 14 Kenyan shillings).
 - (iii) All costs given are per capita.
 - (iv) The costs for cesspools assume water-borne sanitation.
 - (v) The individual owner pays the running costs for pit latrines; all other running costs are paid from public funds.
 - (vi) Except for pit latrines where eight users have been assumed, the costs are based upon an average of five persons using each facility.
 - (vii) In this context 'conventional treatment' of sewage implies a treatment works constructed using permanent materials and providing preliminary, primary and secondary treatment. The oxidation ponds will provide the same degree of treatment as 'conventional treatment' works.

Cost comparisons

Table 4 does not allow simple economic comparison between the various methods. Direct comparison becomes possible when the unit capital costs are converted into annual costs. Figures 1 and 2 have been prepared in this way from the information presented in Table 4. Interest rates of 6% and 10% respectively have been used to compile these two figures.

Conclusions drawn from cost comparisons

The more important conclusions arising from figures 1 and 2 include the following. It should be noted that they are not sensitive to the rate of interest:

- (i) Pit latrines are undoubtedly the cheapest method.
- (ii) Cesspools are relatively very costly.
- (iii) Bucket latrines are more expensive than sewerage, where treatment is by oxidation ponds.
- (iv) Aqua-privies are comparable in cost to sewerage.
- (v) Septic tanks are more expensive than sewerage.

However, as explained earlier, the costs of sewerage are dependent upon a variety of circumstances including ground conditions and population density, so there will be many particular instances where sewerage is more costly than bucket latrines, aqua-privies or septic tanks. Also, as previously noted, the various methods are not strictly comparable and therefore decisions as to which disposal method to choose cannot be based solely upon financial reasoning. Other factors are also important.

FIGURE 1: Comparison between annual costs per capita of various methods of sewage disposal (based upon annual interest rate of 6% and 1977 values)

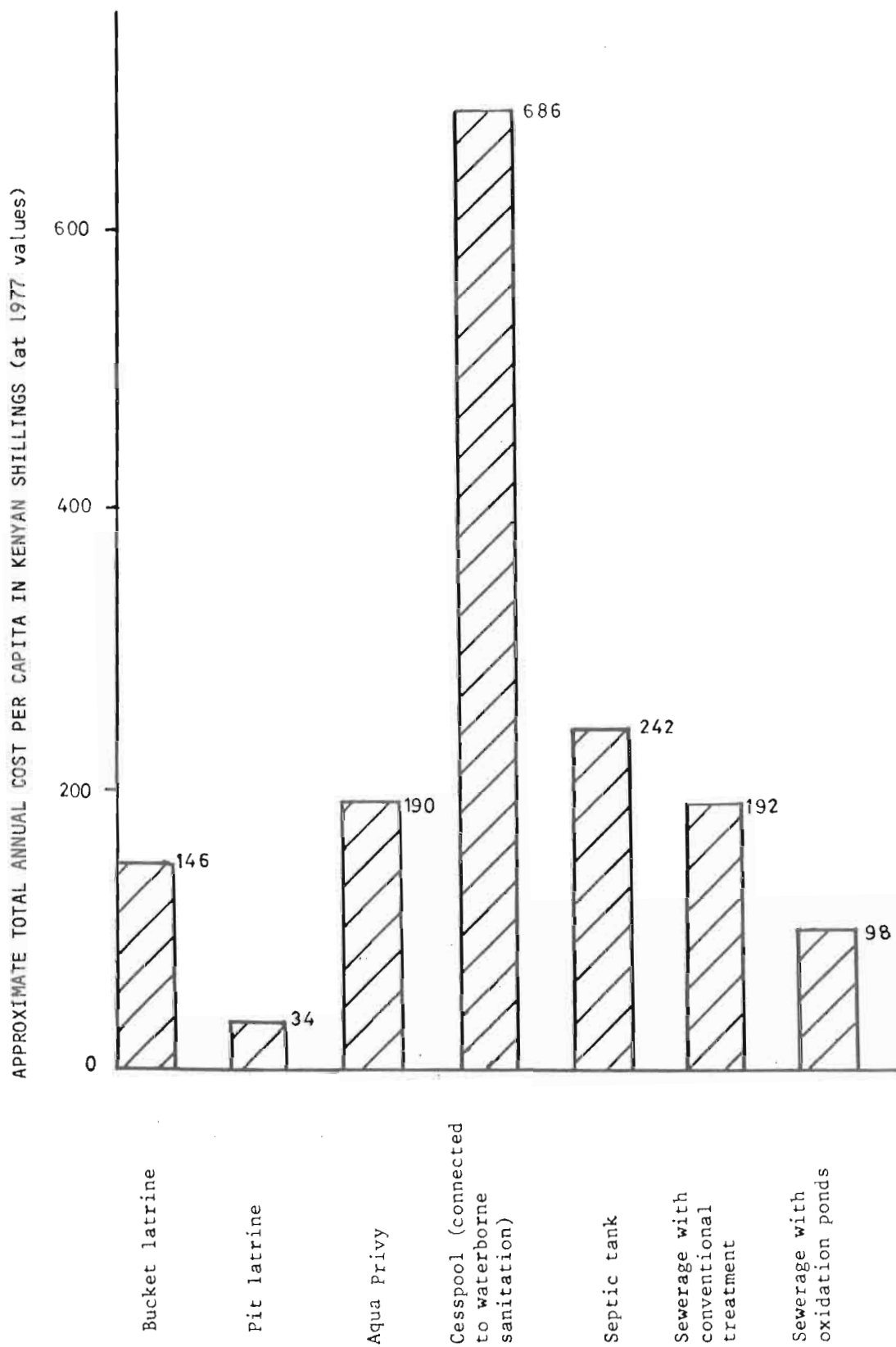
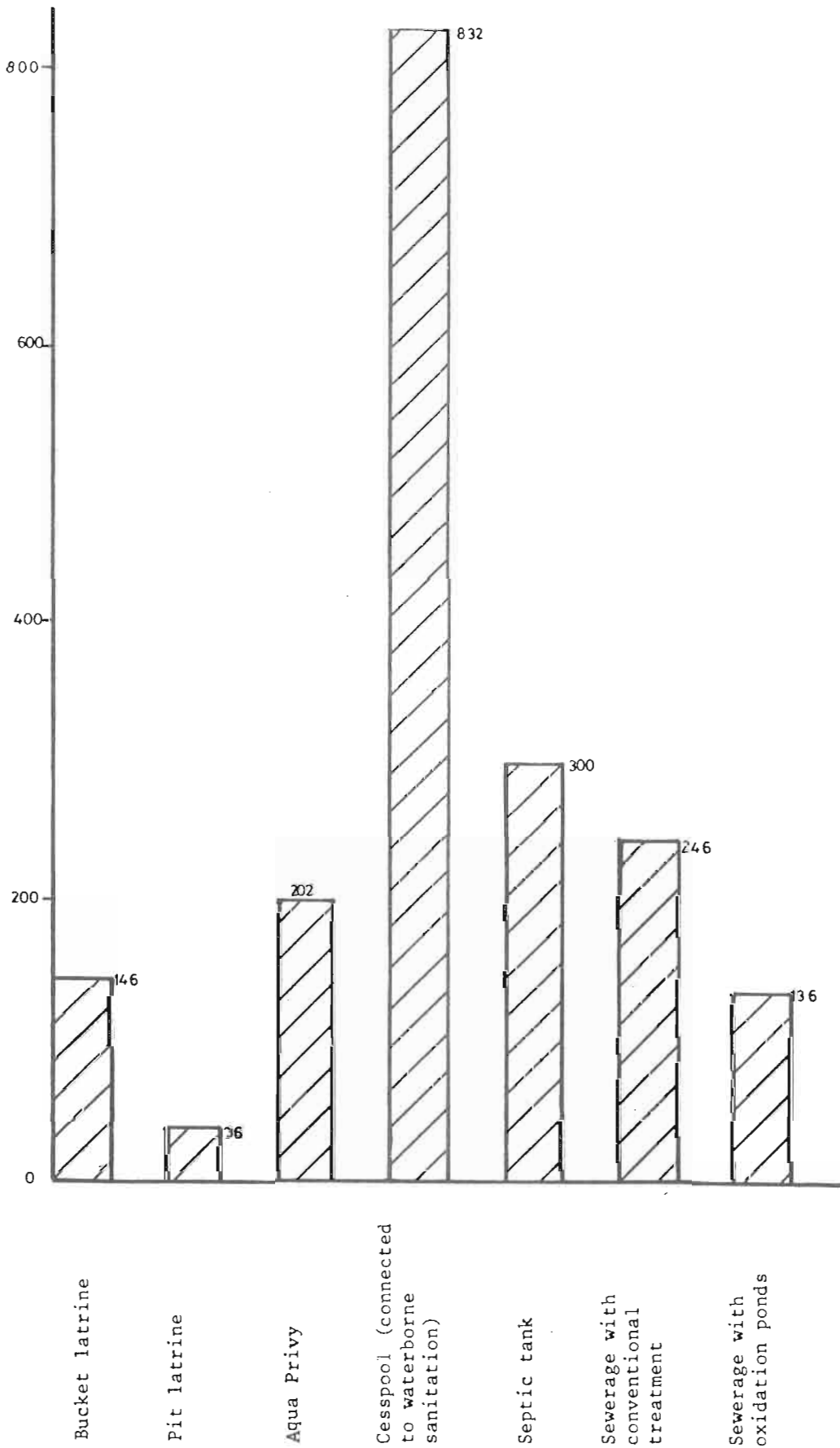


FIGURE 2: Comparison between annual costs per capita of various methods of sewage disposal (based upon annual interest rate of 10% and 1977 values)



5. RECOMMENDATIONS MADE TO THE KENYA GOVERNMENT

The WHO sewage disposal reports included the following recommendations. Implementation commenced during the second phase of the WHO project, with the Sewerage Division within the Water Department of the Ministry of Water Development acting as the national technical agency and advisor.

The term 'sewerage' implies a system of sewers followed by treatment of the collected sewage before disposal. Where there is a piped water supply with individual connections to properties, sewerage is certainly the most convenient, inoffensive and sanitary method of dealing with domestic sewage provided that the system has been properly designed, is well constructed and diligently maintained. This is as true for the individuals served as for the community.

However desirable it is not feasible to provide sewerage for every property in Kenya. It is considered realistic to provide sewerage generally in:

- (i) all urban residential areas where the population density is 50 persons per acre (124 persons per hectare) or more, and also in the business and shopping centres enclosed by these residential areas;
- (ii) the higher density town suburbs located on impermeable ground;
- (iii) the more developed parts of local and market centres located on impermeable ground;
- (iv) all communities of market centre status and above where the water supplies come from local shallow wells.

There will always be a need to install individual-type domestic sewage disposal facilities. Where these are provided, for economic reasons it will not always be possible to provide the best possible of these in every case. The target at which to aim is to ensure that a certain minimum standard and type of facility appropriate to each particular set of circumstances is provided.

Sanitary facilities should be properly selected

The selection of the sanitary method to suit particular circumstances is a fundamental exercise. The selection process was for convenience condensed to the guidelines illustrated on Tables 5 and 6. These relate methods of domestic sewage disposal to the community to the local permeability of the ground and to the type of water supply. In these tables the titles of the methods have been abbreviated as on Table 2.

The types of communities have been summarised into five categories:

Nomadic, with a pastoral population moving with the seasons and therefore living in temporary dwellings.

Low potential rural, which implies a scattered but settled population.

Medium and high potential rural. In this context 'potential' is based generally upon the availability of water and thus covers most areas of higher rainfall.

Low density urban (less than 50 persons per acre, or 123 persons per hectare).

High density urban

TABLE 5: Relationship between the types of water supply, ground conditions and methods of domestic sewage disposal

TYPE OF COMMUNITY	IMPERMEABLE GROUND								
	INDIVIDUAL PIPED SUPPLIES			PIPED COMMUNAL SUPPLIES			OTHER SOURCES OF WATER SUPPLY		
	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum
NOMADIC	-	-	-	-	-	-	Land Bury ¹	Bucket-G Bucket-S	Pit-G
LOW POTENTIAL RURAL (excluding market and local centres)	Pit-G	Pit-S Aqua-privy-G Aqua-privy-S Aqua-privy Septic tank-G Septic tank-S	Septic tank	Bury	Bucket-G Bucket-S Pit-G	Pit-S	Bury	Bucket-G Bucket-S	Pit-S
MEDIUM AND HIGH POTENTIAL RURAL ²	Cesspool-S ⁴ Septic tank-S ⁵	Cesspool	Sewerage	Cesspool-S ⁴ Pit-S ⁵	None	Cesspool	Cesspool-S ⁴ Pit-S ⁵	None	Cesspool
LOW DENSITY URBAN (less than 50 persons per acre) ³	Cesspool-S ⁴ Septic tank-S ⁵	Cesspool	Sewerage	Cesspool-S ⁴ Pit-S ⁵	None	Cesspool	Cesspool-S ⁴ Pit-S ⁵	None	Cesspool
HIGH DENSITY URBAN (50 or more persons per acre and including town centres) ³	Cesspool	None	Sewerage	Cesspool	None	Sewerage ⁶	-	-	-

Notes:

- ¹ Burial is the minimum acceptable method for any nomadic community; land disposal is only acceptable on a journey.
- ² Including market and local centres in low potential rural areas, but excluding rural centres.
- ³ Including rural centres.
- ⁴ For individual plots less than 1/5 acre.
- ⁵ For individual plots 1/5 acre or greater.
- ⁶ Preferably with communal water closets provided by the local authority.

TABLE 6: Relationship between the types of water supply, ground conditions and methods of domestic sewage disposal

TYPE OF COMMUNITY	PERMEABLE GROUND											
	INDIVIDUAL PIPED SUPPLIES			PIPED COMMUNAL SUPPLIES			WATER SUPPLY FROM SHALLOW WELLS			OTHER SOURCES OF WATER SUPPLY		
	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum	Minimum acceptable	Other suitable methods	Realistic maximum
NOMADIC	-	-	-	-	-	-	Bucket-G	Bucket-S ⁴ Pit-G ⁴	Pit-S ⁴	Land ¹ Bury ¹	Bucket-G Bucket-S	Pit-G
LOW POTENTIAL RURAL (excluding market and local centres)	Pit-G	Pit-S Aqua-privy-G Aqua-privy-S Aqua-privy Septic tank-G Septic tank-S	Septic tank	Bury	Pit-G	Pit-S	Bucket-G ⁴	Bucket-S ⁴ Pit-G ⁴	Pit-S ⁴	Bury	Pit-G	Pit-S
MEDIUM AND HIGH POTENTIAL RURAL ²	Pit-G	Pit-S Septic tank-G Septic tank-S	Septic tank	Pit-G	None	Pit-S	Cesspool	None	Sewerage	Pit-G	None	Pit-S
LOW DENSITY URBAN (less than 50 persons per acre) ³	Septic tank-G	Septic tank-S Septic tank	Sewerage	Pit-G	Pit-S Aqua-privy-G ⁵ Aqua-privy-S ⁵	Aqua-privy ⁵	Cesspool	None	Sewerage	Pit-G	None	Pit-S
HIGH DENSITY URBAN (50 or more persons per acre & including town centres) ³	Septic tank-S ⁶	Septic tank ⁶	Sewerage	Aqua-privy-S ⁵	Aqua-privy ⁵ Septic tank-S ⁷ Septic tank ⁷	Sewerage ⁷	-	-	-	-	-	-

Notes:

- ¹ Burial is the minimum acceptable method for any nomadic community; land disposal is only acceptable on a journey.
- ² Including market and local centres in low potential rural areas, but excluding rural centres.
- ³ Including rural centres.
- ⁴ These pit latrines and soakage arrangements must be located with extreme care.
- ⁵ In Moslem communities only, except where the privy also has a shower with piped water.
- ⁶ Septic tanks are communal, not individual.
- ⁷ Preferably with communal water closets provided by local authority.

The Physical Planning Department of the Ministry of Lands and Settlement has classified communities on the basis of a points system. Points are awarded for certain facilities which the community has (for example, hospitals earn three points the same as a fire station, and two points are given for a library). In this way each community is placed in one of the following categories:

Local centres	(8 to 12 points)
Market centres	(13 to 18 points)
Rural centres	(19 to 36 points)
Urban centres	(37 points or more)

Conditions in market and local centres are considered to be more similar to conditions in medium and high potential rural areas, and these communities are therefore included in this category on Tables 5 and 6. Similarly, rural and urban centres are considered as low density urban communities and are therefore excluded from the medium and high potential rural category.

The distinction between 'permeable' and 'impermeable' ground is obviously imprecise. It is intended to establish in Kenya a standard test, probably based upon the rate of soakage of clean water out of a pit of specified size in order to standardise these descriptions.

The volume of water used domestically and consequently the volume of sewage produced, normally depends upon the type of water supply; thus the type of water supply often determines the optimum method of domestic sewage disposal. Tables 5 and 6 distinguish between different types of water supply:

- (i) Individual piped means a supply connected to sanitary fittings, including a water closet, within a building.
- (ii) Piped communal includes water taps located in private plots surrounding houses in addition to communal water points.
- (iii) Water supply from shallow wells implies that water has to be carried a reasonable distance from, for example a village well, to each property.
- (iv) Other sources of water supply include water sources such as springs and watercourses which are far away from the community.

The selection of the most suitable method of domestic sewage disposal depends upon the type and wealth of the community to be served. The two tables give a choice of installation for each set of circumstances, ranging from the minimum acceptable facility to the realistic maximum which is the best it is reasonable to provide. The aim should of course be to encourage people to install in their homes the best appropriate sewage disposal arrangements which they can afford. In particular where there is sewerage and the property is permanent every effort should be made to persuade property owners to have waterborne sanitation, draining into the public sewer.

Sanitary facilities provided should be properly designed and constructed

If they are to operate correctly sanitary installations need to be properly designed and constructed and to be of a size appropriate to the loadings they will receive. The policy recommended to the Government of Kenya was to replace the many and varied 'standard' designs for sewage disposal facilities then current in Kenya by national standard designs backed by law. These designs should specify the appropriate standards of building materials and should be linked to treatment and/or disposal capacity to ensure that units are never in the future overloaded.

The preparation of standards designs is currently in hand. Once completed these designs should not be regarded as fixed. Continuous research and development should take place with the aim of constantly improving details and efficiencies.

Records should be kept of all installations

The foundations for any effective organisation are records and statistics which show the extent of the problem to be tackled. In the present context, records should at the least give the numbers of the different types of domestic sewage disposal arrangement in each community or rural area, plus details of their needs, arrangements and frequency of servicing. Records are slowly being assembled in Kenya.

The supervision and servicing of sanitary facilities should be properly organised and supported by legislation

The WHO reports suggested to the Government of Kenya that it should be the responsibilities of the Government and local sewage disposal authorities to ensure that all sanitary facilities when constructed are appropriate to the circumstances and properly designed and built.

It was recommended that the responsibility of servicing sanitary units rests solely with the appropriate local sewerage authority which, however, should have power to recover the costs of its service from each property owner who benefits. In this context servicing includes emptying bucket latrines, aqua-privies, cesspools and septic tanks at appropriate intervals, and disposing of their contents. The proper maintenance of the units should rest with the owners who should be obliged to ensure their constant hygienic operation. Supervision and servicing require careful planning and organisation both on a national and local level. Also, if they are to be effective the powers and roles of the various sewage disposal authorities need to be backed by appropriate legislation with realistic penalties for non-compliance.

The control and supervision of the selection and construction of domestic sanitary installations can become a relatively simple and routine task once the selection guidelines (Tables 5 and 6) become nationally accepted and standard designs for the various sanitary units have been prepared.

The servicing of large numbers of sanitary installations is not an easy task. It requires not only proper equipment but also considerable planning and control if it is to be effective and economical. Once a successful system has been achieved in a particular community, however, the servicing operations become routine and therefore more easily controlled.

Adequate trained staff should be provided nationally and to the local sewage disposal authorities

The proposed national and local sewage disposal authorities require staff at every level of competence. There is, however, a severe shortage in Kenya of suitably trained and experienced personnel, both professional and sub-professional. As a stop-gap measure professional expatriates fill most of the senior positions. It was recommended to the Government that as a matter of urgency training programmes should be commenced for sub-professionals. The Training School of the Ministry of Water Development with the assistance of Sewerage Division personnel undertook this task on a national scale.

Recruits selected direct from school are given a twelve-month general training in water supply and sewage disposal theory and techniques and allied subjects, followed by a specialist four-month course in sewage

disposal. Local authorities may second their own staff to these specialist courses, provided they have the appropriate education to qualify for entry. The total intake is approximately fifteen each year. The better students (approximately one-third of the total) are then sent to the Nairobi Polytechnic on a diploma sandwich course in sanitary engineering. Plans are in hand to send the very best students overseas to study for first degrees. All Ministry of Water Development students when they leave the Training School receive practical training followed by formal refresher courses, also at the Training School. For a student who does not attend the Nairobi Polytechnic, his theoretical plus practical training lasts three years.

In parallel with these efforts by the Ministry of Water Development, the Nairobi University with the assistance of the World Health Organisation now runs higher degree courses in sanitary engineering for graduates, normally sponsored by the Ministry of Water Development or by local authorities.

Adequate funds should be provided for the sewage disposal authorities

If they are to be implemented, the above recommendations require finance. The successes achieved during the past four years have happily convinced the Government of Kenya of the wisdom of spending funds in this way and at both national and local levels the necessary finance is now starting to be allocated.

Adequate refuse and stormwater drainage collection and disposal arrangements should be provided

It may seem that these problems have little to do with the subject of this paper. However, in fact they are closely allied and if not dealt with in parallel to sanitary sewage disposal, then the potential benefits of sanitation can to a great extent be cancelled. Refuse, or garbage, has many of the undesirable characteristics of sewage and its collection and disposal should similarly be carefully organised and controlled otherwise hazards to public health and the pollution of water resources will continue.

If there is no adequate stormwater drainage flooding will occur. There is no domestic sanitary arrangement which can withstand flooding. Facilities cease to function, giving rise to all the dangers and nuisances to which insanitary installations are prone.

The public should be educated into good sanitary practices

To be successful any programme aimed at improving sewage disposal can only succeed if it has the backing of the majority of the local people. The spread of disease can only be reduced in Kenya if people realise the importance of hygienic habits. Even the best sewage disposal arrangements will not function if they are used incorrectly. If the facilities provided are not utilised or are misused, then their installation was to some extent a waste of money.

The WHO reports urged that every medium for communication should be used to educate and persuade citizens into wanting and using correctly sanitary sewage disposal facilities; public statements by Kenya's leaders, posters, films and demonstrations in remote areas were all suggested as ways of achieving these objectives.

Education by persuasion usually achieves the best, long-lasting results. The recommendations included pilot projects in busy centres during which 'model' latrines are constructed by the local sewage disposal authority

in order to show the public what is required. Another positive recommendation was to provide the best possible sanitation in schools so that the younger generation will become familiar with modern facilities and eventually want them in their homes; guiding school children in this way should help stamp out many social taboos which today hamper the spread of good sanitation.

What is required for success is a national campaign which provides drive and knowledge and also encourages the participation of each family in the form of labour or materials or both. Happily a growing public awareness of the benefits of good sanitary practice is becoming obvious in Kenya's cities and larger towns.

APPENDIX A

CALCULATIONS OF UNIT COSTS FOR PROVIDING, MAINTAINING AND SERVICING DOMESTIC SEWAGE DISPOSAL FACILITIES

The reasoning and calculations which follow are subject to the qualifications described in section 4. The basic costs used and the life expectancies suggested for the various installations are necessarily very approximate, but are considered sufficiently accurate for present purposes. All costs given are in Kenyan Shillings (K Shs) and are based upon 1977 values.

Miscellaneous costs

Ground soakage is common to several methods of domestic sanitation; the problem of periodically collecting and disposing of night-soil (from bucket latrines) or sludge similarly often features. It is therefore a convenient first step to establish unit costs for these processes before considering the various methods in detail.

a) Ground soakage

Ground soakage here implies a sub-surface arrangement which may be either a soakage pit or a shallow piped drainage system dealing perhaps with sullage or with the effluent overflowing from an aqua-privy or septic tank. The size and therefore the costs of an installation will vary with its duty. Typical costs for a soakage unit suitable for a single dwelling range from K Shs.600/= to 1200/=. Five years is an average life before replacement or major extension are required. Untreated sullage would normally clog the ground before this, but a unit dealing with septic tank effluent should last longer.

b) The collection and disposal of night-soil and sewage sludges

Night-soil and sewage sludges should preferably be collected and conveyed by a purpose-made vehicle; pumps rather than hand buckets should be used to empty sewage tanks. For costing purposes it is assumed that night-soil and sludges will be transported to a collection depot and then dumped into trenches and rapidly buried. This is usually the cheapest method, the annual costs per capita varying from approximately K Shs.4/= for septic tank sludges to K Shs.14/= for night-soil from bucket latrines, and to K Shs.28/= for the contents of cesspools.

Bucket latrines should be emptied, washed and disinfected daily; the better method is to have two buckets for each household, one bucket being in use whilst the other is being cleaned, preferably at a central depot. Although ox-carts can be used to convey full buckets to the

disposal/washing depots, purpose-made motor vehicles are more sanitary and much less offensive. For a small town the costs of servicing bucket latrines are approximately the same whether conveyance is by vehicle or by ox-cart: an ox-cart becomes cheaper in larger towns. It has been found that a vehicle costing K Shs.192/= with a total labour force of five men can deal with 300 bucket latrine installations; the cost of servicing one bucket latrine is then approximately K Shs.570/= per year including emptying, conveyance, cleaning and night-soil disposal.

The size of a cesspool is related to the planned period between emptyings. When calculating unit costs the assumption has been made that each cesspool will have a capacity equivalent to 6½ weeks' inflow but will be emptied monthly. A purpose-made tank lorry complete with pump and suitable for cesspool-emptying costs approximately K Shs.240 000/=. Such a vehicle manned by a team of three should be able to deal in rotation with one hundred cesspools; the cost of servicing a cesspool serving a single household is then approximately K Shs.1340/= per year, including disposal of the cesspool contents.

A correctly-sized septic tank requires desludging about once in two years; an aqua-privy, which can be much smaller than a septic tank, should be emptied about twice each year. The better servicing method is to use a cesspool-emptying vehicle. However, a small town in a remote area may not have sufficient work to make economic use of such a vehicle and in such circumstances a simple tank with a handpump and fitted to an ox-cart is an acceptable alternative. A cesspool-emptying vehicle with a gang of four men should be able to deal in rotation with either 5000 septic tanks or 1250 aqua-privies; a simple ox-cart tanker plus five men should be able to service 3000 tanks or 750 privies. The costs of emptying and disposing of the contents of a single domestic tank using a vehicle have been found to be approximately double those when an ox-cart tanker is used. If it is assumed that 20% of all septic tanks and 40% of all aqua-privies are emptied by means of handpumps fitted to ox-cart tankers, then the average total annual costs of servicing a septic tank approximately equal K Shs.80/=; comparative costs for an aqua-privy are approximately K Shs.320/=.

Unit costs for various arrangements

As discussed in section 4, the various methods of domestic sanitation listed in Table 2 do not all perform the same function. An important distinction should also be made between systems such as bucket latrines, pit latrines and aqua-privies, all of which are household excreta disposal units essentially complete in themselves, and cesspools, septic tanks and sewerage which are incomplete units and must normally be supplemented by water closets. Therefore, for true comparison the related necessary costs of supplying piped water and constructing water closets should perhaps be added to the costs of providing cesspools, septic tanks and sewerage.

However, in the following unit cost estimates for cesspools, septic tanks and sewerage, although waterborne sanitation is assumed:

- (i) the costs of water supply and of water closets and other installations within a dwelling are ignored, and
- (ii) The costs of drains connecting the dwellings' conveniences to either a sewage tank or a public sewer are ignored.

It is assumed that the disposal of excreta by simple burial incurs neither capital nor running expenditure.

a) Bucket latrines

Buckets cost about K Shs.80/= each, and two buckets used alternatively may be expected to last one year each before replacement.

b) Pit latrines

Pit latrines are usually constructed by the family who will use them and so the only cash expenditure is normally on materials. However, in order to compare this system with others it will be assumed that labour is employed during construction. A pit latrine with a simple building made using local materials will cost approximately K Shs.500/=. Eight years is a typical life for a correctly-sized pit in appropriate ground. Servicing costs for a typical pit latrine serving one dwelling, including repairs to the building and regular cleaning of the squatting slab using water and disinfectant, are assumed to be approximately K Shs.200/= per year.

c) Aqua-privies

The construction costs of an aqua-privy, including a building made of durable material but excluding soakage arrangements, are approximately K Shs.1600/=. Such a unit should last for fifteen years before major repairs are required.

d) Cesspools

Cesspools are expensive as they are necessarily large and must be made of good materials to ensure water-tightness. However, being of simpler design, volume for volume they are relatively cheaper to construct than septic tanks. Assuming monthly emptying, (viz a capacity equivalent to 6½ weeks' inflow) a cesspool tanking all liquid wastes from a dwelling with waterborne sanitation and other modern water-using arrangements would cost approximately K Shs.24 000/= to construct; its life should be about twenty years.

e) Septic tanks

Septic tanks must similarly be made of sound materials. Excluding ground soakage arrangements, the construction costs of a septic tank to deal with sewage from a dwelling served by a piped water supply and with waterborne sanitation vary from approximately K Shs.6000/= to 10 000/= depending upon whether the sullage is discharged on to the ground surface or into the tank; an average value of K Shs.8000/= is assumed for costing purposes. A septic tank may be expected to have a life of twenty years.

f) Sewerage

Unit costs for sewerage may conveniently be divided into the costs of the sewerage system and those for sewage treatment and disposal. Sewerage system unit costs are very variable depending upon local circumstances including population density, ground conditions and topography, but they are generally independent of the type of sewage treatment or disposal. Based upon persons served, the unit per capita costs of an urban sewerage system for Kenya outside Nairobi may vary from as little as K Shs.240/= in an overcrowded locality to K Shs.1800/= for a spacious suburb; K Shs.800/= is assumed as an average per capita unit cost. Given proper attention, sewers and their appurtenances can be expected to last for forty years without any major repairs.

For maximum efficiency sewers must be regularly flushed and repaired; there may also be pumping stations with equipment consuming electricity and requiring more frequent maintenance. It is assumed that maintenance costs, including labour and transport, are equivalent to 1% of the capital costs of the sewers and buildings, plus 2% of the costs of the mechanical and electrical equipment. With an additional allowance to cover power consumption, the annual running costs for a typical sewerage system in Kenya are approximately K Shs.16/= per head of population served.

Sewage may be treated in many ways before disposal. The most expensive method applicable to Kenya is 'conventional' treatment; the least is treatment in oxidation ponds. In this context conventional treatment comprises screening, grit removal and primary settlement, followed by secondary treatment in filter beds and humus tanks; sludges are digested before running on to drying beds.

The unit costs for conventional treatment are roughly constant for towns with population ranging from about 5000 to 30 000 persons; costs are generally higher for smaller towns and decrease as the population served increases. Unit costs for oxidation ponds are approximately constant, regardless of the population served.

Typical capital costs for conventional treatment in Kenya are K Shs.800/= per head; annual running costs including sludge disposal, repairs, labour and electricity, can be taken as 7.5% of this figure. Although the lives of buildings and concrete units are normally greater than those of equipment, an average life of twenty-five years for all components of a sewage treatment works is assumed.

Comparative unit costs for oxidation ponds are approximately K Shs.240/= per head with annual running costs of K Shs.12/= per capita. These costs are based upon land costing K Shs.30 000/= per acre. Oxidation ponds are large in area and their costs are therefore very sensitive to land values.

APPENDIX B

SOURCES OF UNIT COSTS GIVEN IN APPENDIX A

Kenyan costs for sanitary installations and their servicing were discussed with many persons with local knowledge - Ministry and local authority officers, consulting engineers and contractors. The costs so obtained were checked with the World Health Organisation and also with those given in publications usually concerning other countries. Specific publications consulted include the following:

1. Several publications of the Central Public Health Engineering Research Institute of Nagpur, India.
2. Rural sanitation in the tropics (1968). The Ross Institute, the London School of Hygiene and Tropical Medicine.
3. Aspects of water pollution control (1961). World Health Organisation. Public Health Paper no.13
4. Excreta disposal for rural areas and small communities (1958). World Health Organisation, Monograph Series no.39
5. Waste stabilisation ponds (1971). World Health Organisation, Monograph Series no.60
6. The design and construction of the pit latrine. World Health Organisation local publication, Kenya-2/PL/69
7. The economics of wastewater treatment. Townend (1962). Journal of the Institute of Sewage Purification, vol.62, part 3.
8. The cost of sewage treatment. Bradley & Isaac (1969). Journal of the Institute of Water Pollution Control, vol.68, no.4
9. Government of Kenya sectorial study and national programming for community and rural water supply, sewerage and water pollution control. WHO, 1972. Report nos 3,8 and 13