A DIRECTORY OF ENVIRONMENTALLY SOUND TECHNOLOGIES FOR THE INTEGRATED MANAGEMENT OF SOLID, LIQUID, AND HAZARDOUS WASTE FOR SMALL ISLAND DEVELOPING STATES (SIDS) IN THE INDIAN, MEDITERRANEAN AND ATLANTIC REGION

UNEP

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Adapted from the UNEP Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquid and Hazardous Waste for Small Island Developing States (SIDS) in the Pacific Region

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PREFACE

As highlighted in the 1994 Barbados Programme of Action and the 1999 Special Session of the UN General Assembly held in September 1999, the problem of waste management is a major area of concern for Small Island Developing States (SIDS). SIDS like other developing countries, face similar waste management problems. Many SIDS, however, experience additional constraints arising from small land area, high dependence on imports and high population densities exacerbated by high tourist inflows.

This volume is part of a series of publications on waste management in SIDS prepared by the UNEP's Division of Environmental Policy Implementation. The publications were prepared as part of the UNEP project *Integrated Waste Management in SIDS in the Indian Ocean, Mediterranean and Atlantic (IMA) Regions*, which was implemented by the Indian Ocean Commission (IOC). The series consists of the following documents (i) Strategic Guidelines for Integrated Waste Management in SIDS (ii) IMA-SIDS Waste Management Strategy with special emphasis on Minimisation and Resource Recovery (iii) A Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquids and Hazardous Wastes in the Pacific and (iv) A Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquids and Hazardous Wastes in IMA- SIDS.

The Strategic Guidelines for Integrated Waste Management in SIDS were developed on the premise that, if systematic improvements are introduced at the various stages of the waste cycle, the quantity of waste to be managed at each of the subsequent stages would be reduced considerably. It is argued that there should be appropriate and adequate integration and co-operation between stakeholders at the different stages of waste management, based on the vision of achieving "zero waste" to be managed.

These guidelines were prepared using inputs from the Caribbean, Pacific and IMA regions and later reviewed at the UNEP Meeting of Experts on Waste Management in Small Island Developing States organised in London by the Islands and Small States Institute in collaboration with the Commonwealth Secretariat, fròm 2 to 5 November 1999. They were endorsed later that at a meeting of experts held in Mauritius from 22 to 24 November 1999 under the auspices of the Indian Ocean Commission.

The second document included in this series is the *IMA-SIDS Waste Management Strategy with special emphasis on Minimisation and Resource Recovery.* All IMA-SIDS have problems in disposing of wastes regardless of the economic status. A well-managed environment is critical for SIDS since two of their major industries; tourism and fisheries heavily depend on the state of the environment. The threat of disease outbreak will have terrible repercussions on the tourist industry and, the destruction of fisheries, can have enormous negative economic impact.

UNEP, in its programme of support for IMA-SIDS has assisted the region to develop the strategy as a follow-up of the Valetta Declaration, adopted in Malta in November 1998, and of the UNEP Meeting on Integrated Management of Wastes in SIDS in the Indian and Atlantic Ocean SIDS organised by the Indian Ocean Commission (IOC) in December 1997. The waste management strategy adopted at the UNEP/IOC meeting identified the need to adopt a regional approach to waste minimisation as one of the priority issues.

The components of the strategy were identified during the IMA-SIDS Meeting of Technical Experts on Integrated Waste Management and Waste Minimisation in Small Island Developing States held in Mauritius from 22 – 25 November 1999. The strategy was prepared by the Indian Ocean Commission, reviewed and endorsed by the IMA – SIDS High Level Meeting of On Integrated Waste Management and Waste Minimisation in Small Island Developing States from 14 to 15 December1999 in Mauritius.

The Directory of Environmentally Sound Technologies for Integrated Management of Solid, Liquid, and Hazardous Waste for Small Island Developing States (SIDS) in the Pacific Region was compiled by the UNEP International Environment Exchange Centre (IETC). Many times, waste management technologies are transferred from larger and more developed countries, and as such are not always suitable for SIDS. Some SIDS have developed appropriate technologies, which have been successfully employed, but the information has not been shared with other SIDS in the same regions or in other regions. Hence the need for the Directory which compiles a list of practical technologies applicable to SIDS. The Directory is not meant as a technical manual, but as a source of information. The Directory was reviewed during the UNEP Meeting of Experts on Waste Management in Small Island Developing States Waste Management in SIDS, held in London from 2 and 5 November 1999.

The Directory for the Pacific regions was reviewed and endorsed at the IMA–SIDS Meeting of Technical Experts on Integrated Waste Management and Waste Minimisation in Small Island Developing State held in Mauritius from 22 to 25 November 1999. The Indian Ocean Commission adapted the Directory to suit the IMA-SIDS region and produced the fourth document which is *A Directory of Environmentally Sound Technologies for the Integrated Management of Solid, Liquid, and Hazardous Waste for Small Island Developing States (SIDS) in the Indian, Mediterranean and Atlantic Region.*

It is hoped that these publications will make a useful contribution to the promotion of integrated waste management in SIDS in particular those in the IMA regions, and will foster an increased awareness about the special circumstances of SIDS, especially the fact that these states face special constraints in their options for sustainable development. Additionally the material will be useful background to the GPA efforts toward the sewage conference framework and its five year review.

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CONTENTS

1.0 Introduction

Prior to the introduction of imported goods, and packaging, the waste produced from a typical small Island was entirely organic in origin, and could be broken down or composted without thought or problem. To varying degrees, the majority of small Island have now moved from this lifestyle toward a cash based; consumer goods society. This shift can be attributed to western influences, tourism, imported goods, and effects of expatriate communities.

As a result, waste products which do not break down easily, and which are harmful to the environment have increased to the point where significant problems are being experienced. In the majority of cases, Small Island Developing States (SIDS) have not been aware of the need, or have not been able, to develop suitable waste management systems to cope with these changes in waste character.

Environmentally Sound Technologies (ESTs) are therefore needed for the IMA/SIDS region to help solve the problems that now exist, and to ensure that further environmental, and health related problems do not occur as a result of solid waste.

In 1996, the United Nations Envrionment Programme's (UNEP) International Environmental Technology Centre (IETC) published the "International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management" (Technical Publication Series No. 6). This book presented information about different Municipal Solid Waste Management (MSWM) technologies that are currently used in different regions of the World, and gave a guide as to which of these are economically feasible, and Environmentally Sound Technologies (ESTs).

The task of identifying ESTs is complicated by the fact what constitutes an EST is highly dependent on the environmental, economic, climatic, and social context in which the technology is set.

It is for this reason that this current directory has been prepared, to identify and describe ESTs which are suited to the environmental, economic, climatic, cultural, and social context of the IMA/SIDS Region. This directory is structured around 7 separate topics, namely:

a. Waste Reduction
b. Storage, Collection and Transport
c. Composting
d. Incineration
e. Landfills
f. Hazardous Waste
g. Waste Water Technologies

It needs to be stressed at this point that the use of particular techologies such as are discussed in the following pages must be integarted into an overall waste management strategy to be effective.

The UNEP International source Book on Environmentally Sound Technologies for Municipal Solid Waste Management defines a "Sound Practice" as *"a technically and politically feasible, cost effective, sustainable, environmentally beneficial, and socially sensitive solution to an MSWM problem".*

Extending this definition to the Region, a sound practice not only achieves the management of municipal solid waste, but in the process, takes into account the specific physical, environmental, social, and political background conditions of the area. For the SIDS of these background conditions (which tend to make solid waste management difficult) include:

- High population density and competition between land uses
- relatively small watersheds and threatened supplies of fresh water;
- limited institutional capacities and domestic markets;
- limited export volumes (leading to high freight costs and reduced competitiveness)
- high tourist numbers,
- poor planning
- low levels of education, and
- fragile environments,

Alternative technologies and waste management strategies need to be evaluated to identify whether they fit in with the background conditions of the IMA region, and hence whether they are "sound".

2.0 Solid Waste Management Technologies - Choice of Alternatives

(a) Is the option likely to accomplish its purpose in the circumstances where it would be used?

(b) Is the option technically feasible and appropriate given the financial and human resources available?

(c) Focusing on the financial aspects of the option, is it the most cost-effective option available?

(d) What are the environmental costs and benefits of the option?

(e) Could the environmental soundness of the option be significantly enhanced, given a small increase in cost?

(f) Conversely, would it be possible to significantly reduce the cost, with only a small detriment to the environment?

(g) Is the practice administratively feasible and sensible?

(h) Is it practical in the given social and cultural environment?

(i) How would specific sectors of society be affected by the adoption of this option?

(j) Do these effects promote or conflict with overall social goals of the society?

The following guidelines are also recommended for technology selection :

A. The technology should be suited to the local environment economically and culturally.

B. The operation and maintenance should be easily undertaken using local manpower.

C. The technology should be simple and easily understood by the local people, and have a certain flexibility for possible changes.

D. The technology should use, whenever possible, local materials an energy sources. Where imported materials are recommended, they must be affordable and easily obtainable.

E. The technology, whenever possible, could be sited in existing high-density areas.

F. The technology should not directly or indirectly contribute to the pollution and destruction of the existing ecology.

G. The technology should enhance health and sanitation aspects, and upgrade the economic well-being of the community.

Background Conditions that affect the selection of an EST in the IMA Region

The following is a list of the SIDS of the IMA Region;

- Bahrain
- Cape Verde
- Comoros
- Cyprus
- Guinea Bissua
- Madagascar
- Maldives
- Malta
- Mauritius
- Sao Tomé and Principe
- Seychelles

The factors that may be used in assessing the background conditions present for individual situations are :

Level of Development:

- The economic development, including relative cost of capital, labour and other resources
- The technological development
- The human resource development, in the municipal solid waste field and in the society as a whole

Natural Conditions:

- The physical conditions, such as topography, soil characteristics, and type and proximity of bodies of water
- The climate including temperature, rainfall, tendency for thermal inversions, and winds
- The specific environmental sensitivities of a region.

Conditions arising from Human Activities:

- The waste characteristics including density, moisture content, combustibility, recyclability, and presence of hazardous waste in MSW
- The population characteristics such as population size, density, and infrastructure development

Social and Political Considerations:

- The degree to which decisions are constrained by political considerations, and the nature of these constraints

- Degree of importance assigned to community involvement (including that of woman and the poor) in carrying out MSWM activities
- Social and cultural practices.

2.1 Waste Reduction

Currently, there is very limited waste reduction activity in IMA SIDS. This is due to a combination of factors including:

- smallness and remoteness handicaps the implementation of economically sound waste management plans;
- Limited financial resources are available to subsidise schemes such as recycling, central composting etc.
- Limited internal market for recycled goods
- A large number of goods are imported and hence there is very little possibility to influence product design or to minimise waste generation such as packaging materials.

As a consequence, the quantity of waste generated through imported goods, and other activities, is the same as the quantity of waste disposed of by burning, dumping in the sea, or landfilling.

The key concepts of waste reduction are:

- Reducing waste at the source,
- Source separation of waste,
- Waste and materials recovery for re-use
- Re-cycling waste materials
- Reducing use of toxic or harmful materials

Waste reduction is the first line of attack for solid waste management. Waste reduction minimises the quantity of waste produced, thus reducing all other costs down the line, such as collection, transporting, and disposal. Disposal sites last longer, and costs are reduced by using resources more efficiently.

In the IMA SIDS region, almost all islands are small and remote, with limited or no suitable area for disposal by landfilling. This makes waste reduction even more crucial to ensure sound MSWM.

Tools for Environmentally Sound Technologies for Waste Reduction

The following "sound practice" tools for promoting waste reduction and materials recovery were identified by the UNEP International Source Book. Each of these tools are evaluated below in terms of sound practice against existing background conditions in SIDS:

1. *Promote educational campaigns*

   Education of both government authorities responsible for waste management, and the general public is identified as one of the most critical actions necessary in SIDS to help find solutions to the solid waste problems. Government authorities should seen to lead good waste management practice for example by instigating waste reduction measures in the office, such as re-use of envelopes etc.

This education should also inform people of the environmental, health, and economic impacts of the current solid waste generation and disposal habits. Such education will help give public ownership of the problem, and should help promote involvement by the public by providing information on methods of waste reduction, recycling, and materials reuse that they can adopt at a household and village level. Increased public awareness may also lead to pressure being applied to importers to them to avoid the purchase of high waste, or non-biodegradable products.

2. *Study waste streams (quantity and composition),*

   Very little information has been gathered regarding the quantity and composition of the waste streams from SIDS. This information is crucial to enable the setup of recovery and recycling systems, markets for recyclables, and to identify problems within existing WM practices. Where appropriate, the local municipal authority can then take a facilitative/regulatory role.

3. *Facilitate small enterprises and public-private partnerships by new or amended regulations*

   This is due to take place in Mauritius with the forthcoming regulations on the polymer Polyethylene terephthalate (PET - soft drinks). The aim of this regulation is to develop 'product responsibility' in the bottlers of soft drinks for the proper management of the bottles even after it has been sold. It is proposed to establish a deposit - refund system within the regulation which will encourage the return of the PET bottles. A deposit will be paid when the consumer purchases the soft drinks in PET bottles and money will be refunded when the empty bottle is returned. This will provide an incentive for the collection, re-export/recycling and proper disposal of the waste materials. One of the responsibilities of the bottlers will be the setting up of a mechanism for the collection and proper disposal of the plastic bottles (including re-export, possible local recycling and as a last resort, sound disposal).

4. *Assist waste pickers*

   As there is little if any waste picking done on SIDS, assistance in this is not needed. However, where there is informal interest in waste picking, or small enterprise this should be encourage along with some general guidelines to minimise health and safety problems relating to waste picking are minimised.

5. *Reduce Waste via legislation and economic instruments*

   The majority of non-biodegradable waste in SIDS waste streams is derived from the importation of packaged goods. Packaging could be reduced through selective waste reduction legislation. The region is at the end of the line for many waste streams generated by manufacturing countries. Special measures, for example surcharges, taxes, or deposits, may be justified for plastics, cans or bottles. Funding thus obtained could be used to ensure these materials can be sorted and backloaded to destinations where recycling can be carried out.

6. *Export re-cyclables*

   For SIDS, export of re-cyclables is really only possible for materials that have sufficient value, such as crushed aluminium cans.

7. *Promote innovation*

To create new uses for goods and materials that would otherwise be discarded after initial use.

Given the relatively low labour cost in the SIDS, value could be added to recovered waste materials by making the materials into new products. This type of enterprise would require investigation of potential markets. These could be to the local public, to tourists, or for export.

8. *Reducing use of substances which produce toxic, or hazard waste*

This can be done through education of the public, providing information on hazardous or toxic goods, alternative products that are not toxic or hazardous, and implementing legislation which prevents the importation of such products.

2.1.1 Reducing Plastic Wastes

Today plastics play a major role in the island societies. It is estimated that in islands of the IMA region, plastic wastes account for 3 to 10 % of the Municipal Solid waste. The following methods (instruments) are used to reduce the plastic wastes.

(a) Legal instruments

The use of the legal instruments to manage plastic wastes should be given due consideration and should be within a framework of an integrated waste management policy. Factors that influence such a choice are:

- Institutional arrangements that take into account logistic realities of landfills. Landfills are filling too quickly and it is difficult to find new sites.
- Management of litter.
- Current methods of disposing of plastics by industry and population (Uncontrolled burning).
- Level of awareness of population.
- Experience acquired with voluntary schemes of reduction of wastes.

  The agreement of the national authorities with industry or trade on the voluntary observance of certain goals relating to reuse or recycling of plastic is often not effective. Practice has shown that in European countries also such voluntary agreements quickly reach their limits in open economies. Participants in such schemes are not willing to invest in systems of collection, transport, recycling/disposal if there is no guarantee that this investment will pay off. In these schemes there is a lack of sanctions against companies which do not adhere to the agreement and this undermines wider participation.

The legal approach enjoys the benefit of simplicity and familiarity, as well as enforceability.

Some examples of regulations are :

1. PET regulations

   The aim of such a regulation can be to develop 'product responsibility' in those putting the bottles on the market . The term 'product responsibility' means that the manufacturer of an item is also responsible for its proper disposal even after it has been sold. Such a regulation can establish a deposit - refund system so as to encourage the return of the PET bottles. A deposit is paid when the consumer purchases the soft drinks in PET bottles and money is refunded when the product is returned after use, this will provide an incentive for the collection, re-export/ recycling and proper disposal of the waste materials. One of the responsibilities of those putting the bottles on the market is the setting up of a mechanism for the collection and proper disposal of the plastic bottles (including re-export,possible local recycling and as a last resort, sound disposal).

2. Encouraging alternatives and reuse

   Such a regulation can stipulate that all refreshment drinks should be bottled in refillable glass bottles and also establish a mandatory refundable deposit on the containers. In Malta: Non-alcoholic Beverages (Legal Notice 183 of 1994 - Control of Containers) Regulations mandates that, with the exception of essence or syrup intended for the manufacture of soft drinks, water, electrolyte-replacement drinks, milk, tea, coffee, cocoa, fruit juices, nectars and squashes, all refreshment drinks containing not more than 2 per cent alcohol shall be bottled in refillable glass bottles. It also establishes a mandatory refundable deposit on the containers.

(b) Economic Instruments

This approach attempts to change the behaviour of market players by including the full cost of environmental damage with the price of a product or a service. According to the polluter pays and user pays principles, all waste producers should pay directly for the full costs of collection, treatment and disposal of the waste they produce. If properly applied, these market instruments encourage waste producers to reduce the amount of waste they create and make waste recycling more economically viable.

Although there are some problems with economic instruments, they, however, provide many advantages too:

- they tap on the economic sense of producers and consumers leaving flexibility in response.;
- they encourage innovation;
- they generate revenue that may, in turn, be earmarked for waste management programs or revenues could be used to set-off reductions in other taxes.

There are of course a number of difficulties associated with economic instruments, such as lack of experience in how to implement them and resistance by the public.

Economic instruments that can potentially be adopted in order to minimise plastic waste are:

1. Charges

   Such fees can be introduced in a phased manner as waste disposal charges (tipping fees at all landfills) to cover industrial solid waste.. This can encourage the industrial sector to innovate or establish waste exchange scheme.

2. Subsidies / assistance

Recycling activity, which is often not viable from a strictly profit making perspective may need to be supported by government assistance.

The recycling industries are usually located in cheaper, older buildings,and are seen as "bad neighbours" due to the unsightly storage of materials, noise from compaction and baling, odour from the waste, and litter in the vicinity. The uncertain accommodation situation, together with fluctuations in market prices for marginally profitable products, discourages recyclers from investing in new, perhaps more environmentally friendly technology, and might inhibit increased recycling. The following arrangements should facilitate waste recycling efforts:

- leasing appropriate short term tenancy sites to the waste recycling industry for up to 5 years;
- using restored landfill sites for waste recovery and recycling facilities;
- publicising the availability of industrial land/premises suitable for the recycling industry;

3. Deposit Refund Schemes

Deposit refund schemes are a combination of a tax and subsidy. Here consumers have the right of refund having paid a subsidised deposit on purchase.

2.1.2 Reducing Tyre Wastes

Many used tyres (part-worn) can be re-used for their originally intended purpose. It should have a minimum tread depth remaining and ,subject to examining of the structural soundness, does not show wear affecting its safe and proper functioning. Road specifications exist in some countries prescribing the minimum tread depth(1,6 -passenger car tyre) for part-worn tyres.

The used tyre that cannot be re-used for its originally intended purpose is often suitable for retreading. This maximizes tyre utilization as 80 % of the original material is available for reuse. The tyre can be reprocessed whereby new tread is vulcanized to the casing and the used tyre becomes a retreaded tyre.

Used tyres that cannot be reused for its original purpose and that is not suitable for retreading, is worn out. Such a tyre is called end-of life.

The management of end-of life tyres depends on local economic and industrial conditions. These can be

- reused directly or indirectly (material recycling)
- used for energy recovery
- landfilled

Direct reuse

The end-of- life-tyres in whole, cut or stamped form can be used directly in many environmentally sound applications. The following is a list of some of the uses of the worn out tyres :

- as coastal protection and off-coast break waters;
- in civil engineering works e.g highway crash barriers, sound absorbing walls, boat fenders on harbour walls;

- as insulation in buildings foundations and road based material;
    - to consolidate steep slopes on roadway sides;
    - as cover material in agriculture applications and for landfills

Material recycling

End -of -life tyres can be shredded to facilitate transport, as a first step towards granulation,or for use in several applications.

The tyres are fed into shredder and in most circumstances, the steel and textile are not removed, but may include the additional process of material separation. The shredder can be mobile or fixed. Regions which permit landfilling of these tyres often require that they are shredded in order to mimimise the space requirements and to reduce the potential of the tyres rising to the surface once the landfill has been capped. Tyre shred can be used as a secondary fuel for incineration or as first step in the granulation process , or may be utilized as daily cover for landfills.

These worn out tyres can be used to produce rubber crumb or granulate. There are two principal methods of granulating end-of-life tyres.

Grinding at ambient temperature : The tyres are shredded and then fed into a grinding mill. After grinding, the material is separated into rubber granulates, steel and textile ; the granulate can be sieved into different particle sizes.

Grinding at very low temperature(cryogenic method). In this process the end-of-life tyre and chopped rubber has to be cooled to below the freezing point, after which it is ground in a hammermill. This process enables rapid separation of fibres, metals and rubber.

The following table gives an overview of granulating treatments.

Table I : Overview of Granulating Treatments

Item	Ambient	Cryogenic
Feedstock	Tyres, prodution waste	
Capacity Energy	± 20 000 t/y 125 kwh/t	± 2 000 t/y 150 kwh/t + nitrogen
Product Size	<0.5 -+ 25 mm	<0.5 -+ 5 mm
Emissions	Dust: ± 0.2 kg/h SOx = NO x = 0	Dust: + 0.4 kg/h SOx = NO x = 0
Maintenance	Blades	Nitrogen
Investment costs*	2 - 3	4 - 5

* Based on a scale of 1-5, 5 being the most costly in terms of initial investments

1. a simple shredder
2. ambient granulator (single process)
3. ambient granulator with additional separating capacity
4. basic cryogenic
5. muti- process cryogenic

Some of the many products which can be manufactured from different sizes of rubber granulates are:

- flooring and surface for indoor and out door sports (granulate size, 1.6mm);
- roofing materials;
- carpet underlay (granulate size , 0.6 -2.0 mm);
- road surfaces (modification of bitumen with rubber);
- compounding material in rubber industry for various applications;
- porous drainage materials ;
- children's play grounds (granulate size, 1.6 -2.5 mm);
- road furniture including crash barriers, speed bumps, among others;

Energy recovery

End -of- life tyres provide the same heat energy as that achieved by coal. The net calorific value of a tyre is between 32 and 34 MJ/kg. A tonne of tyres is equivalent to one tonne of good quality coal. or 0.7 tonne of fuel oil.

Whole or shredded worn out tyres can be used as a principal or secondary fuel source in the production of steam, electricity, cement, lime and in the incineration of waste. The incineration of the worn out tyres in small quantities mixed with household refuse is common. The operation of the furnace does not seem to be adversely affected provided the tyres do not account for more than 10 % of the total weight. Essentially, tyres serve to fill gaps in heat production when the net calorific value of the household drops.

Landfilling

Tyres can be efficiently used to prevent damage to the landfill cover, to avoid side-slope erosion, to protect drainage piping and to allow percolating fluid and gases. Advantages of disposing of end-of-life tyres in landfills are low investments and running costs, the ease of management, and the possibility to use the end-of-life tyres for better landfill management.

2.2 Storage, Collection and transfer

2.2.1 Estimating Waste Quantities and Characteristics

Measuring waste quantities and characteristics is aimed at ensuring adequate capacity for waste collection, recycling and disposal. The waste service must be able to cope with the daily and seasonal fluctuations, so measurement of variability is important. Waste quantities may be measured at a number of different points along its route from generation to final disposal.

To have an accurate assessment of total waste quantities, surveys should be conducted for each type of waste. Determinations need to be made of the quantity of residential waste per person in each income area, quantity of commercial waste per employee or per area of shop, the quantity of hospital waste per bed, the quantity of industrial waste per employee or production quantity for the nature of manufacturing conducted, and the quantity of street sweepings per kilometer of curbside.

The residential areas which represent the different socio-economic population groups (income levels : low, middle and high) must be defined.

- Identify around 100 households for each of the residential areas defined and then distribute plastic bags for the storage of the wastes generated.
- Survey the households selected during the distribution exercise so as know the number of persons in each household.
- Collect waste generated once a day for 8 successive days to allow variation in waste generation over a week. Disregard the first day's collection as this might contain waste for more than one day.
- Weight and record total weight of bags and contents.

The Mean daily generation rate = Total weight /number of persons in all /7 (Kg /person /day)
In estimating waste generation quantities, it is necessary to multiply the per capita rate of waste generated by the number of individuals in the collection area.

Around 25 plastic bags are then selected randomly from those collected in each sample area. These bags are then opened and the contents emptied into a bucket until it becomes full. The bucket is then emptied and the contents spread over a plastic sheet. The process is repeated until all the bags for each sample area are emptied. The number of bucket loads emptied are recorded.

The waste on the plastic sheet are separated into different types (e.g Putrescible matter/vegetable, bones, paper, textiles, plastics, grass / leaves / wood, leather / rubber, metals, glass / ceramic, miscellaneous) The separated waste are then put into different buckets for weight measurements.

The weight of each type of waste can then measured and recorded as follows:

	Total Weight	**% Composition**
Putrescible matter/vegetable	W 1	W 1 / W x 100
Bones	W 2	W 2 / W x 100
Paper	W 3	W 3 / W x 100
Textiles	W 4	W 4 / W x 100
Plastics	W 5	W 5 / W x 100
Grass / leaves / wood	W 6	W 6 / W x 100
Leather / rubber	W 7	W 7 / W x 100
Metals	W 8	W 8 / W x 100
Glass / ceramic,	W 9	W 9 / W x 100
Miscellaneous	W10	W10 / W x 100
Total	**W**	**100**

The sampling study should therefore be repeated at a later date to assess seasonal variations.

2.2.2 Sound practice in the design or choice of waste containers

The storage of Municipal Solid Wastes in most of the low-income islands of the region is effected at communal points. The use of such containers may reduce the cost of waste collection. However there are inherent problems associated in the use of such containers, namely:

- The removal and transfer of the wastes from these to the collection vehicles may be difficult and time consuming
- Irregular collection and removal of the wastes can result in these being set on fire or in illegal dumps being established at the location
- Scavengers and animals may have access to the wastes
- Direct contact of the collecting crew with wastes

Thus these containers should be appropriately selected or designed
The following principles are recommended when choosing or designing a new system of set-out containers:

Choose containers made of local, recycled, or readily available materials. Examples used within SIDS include 200 litre drums cut in half, or recycled tyre rubber formed into containers. These should be preferably have lids on the top and be easy to open and empty, dog proof, and of sufficient size and number to hold the expected waste quantities produced and prevent spilling.

Set out Containers can be made from a wide variety of materials (Credit: UNCHS (Habitat)).

- Choose containers which are sturdy and/or easy to repair or replace.
- Consider identification of containers with the waste generators name or address. This helps give more of a sense of ownership and participation in the waste collection process.
- Choose containers that suit the collection objectives.
- Where separation of organic waste and or recyclable waste is proposed, more than one collection container will be necessary. These containers should be clearly distinguishable. E.g. of different size or colour.
- Choose containers that are appropriate for the terrain. On wheels where there are regular paved streets, water proof in areas where rainfall is significant, and heavy and squat where there are often strong winds.

2.2.3 Sound practice in the choice of collection vehicles

The choice of waste collection vehicles is dependent on numerous factors including the method of solid waste collection adopted, the nature and density of the waste, the topography of the island, the available budget, and the distance to the disposal site.

The following table details different collection vehicles available:

Table II Different Types of Collection Vehicles available in the Region

Type of Collection Vehicle	Extent/potential use in IMA SIDS	Comment
Small dumper trucks	Commonly used	- based on modified jeep or 4WD, - smaller capacity
Fore-and-aft tipper/compaction truck	Known to be used in Malta	- enables mechanical loading from transfer bins, and compaction of waste. Not suitable in most SIDS
Tractor and Trailer	Commonly used	- easily used for other work apart from waste collection
Conventional Truck	Commonly used	- can be used for other work apart from waste collection
Roll Top truck	Not likely to be used	- more difficult to utilise for other uses - can have compartments for keeping different wastes separate for recycling or composting
Highside open-top truck,	Commonly used	- suitable for large loads. Could be used in combination with small collector
Human drawn handcart, Animal drawn cart, and human pedal cart.	Known to be used in Comoros	These types of micro-collection vehicles are inexpensive to build and maintain, and therefore are often far more sound compared to motorised vehicles. - likely to be hard to persuade locals to used these.

The type of vehicle selected should also be evaluated in terms of relative capital cost and labour inputs, maintenance requirements, and local availability of technical repair expertise and parts.

Given the isolation of most of the islands, it is recommended that a vehicle type be chosen which is already in use on the island, or within the country.

The following table compares the characteristics of the main waste types of collection vehicles

Vehicle Type	Gross Vehicle Wt. (Kg)	Body Capacity (Cu m)	Operating Range (short/ medium /long)	Loading Speed(short/ medium/fast)	Labour Requirement	Capital Cost Per Volume of waste collected	Running cost	Economic life of vehicle	Manoeuvrability	Suitable for local body Manufacture
Non-Motorised Systems										
Hand Cart	-	0.4	Short	Fast	High	Low	Low	Long	Good	Yes
Pedal Tricycle	-	0.4	Medium	Fast	High	Low	Low	Long	Good	Yes
Animal Cart	-	2.0	Medium	Fast	Medium	Low	Low	Medium	Good	Yes
Non-Compaction Systems										
High-Side Open Body	10 000	10	Long	Slow	High	Very High	Medium	Short	Poor	Yes
Side Loading Roll Top	6 000	6	Long	Medium	Medium	High	Medium	Short	Medium	Yes
Tractor and Trailer	6 000	6	Medium	Medium	Medium	High	Low	Medium	Medium	Yes
Front Loading Body	8 000	10	Long	Slow	Medium	High	Medium	Short	Medium	Yes
Fore & Aft. Tipper	8 000	10	Long	Fast	Low	Medium	Medium	Short	Medium	Yes
Three Wheeled Auto Rick shaw	2 000	3	Medium	Fast	Medium	Low	Low	Short	Good	Yes
Dumper - Tipper	2 500	3	Medium	Fast	Medium	Low	Low	Medium	Good	Yes

Vehicle Type	Gross Vehicle Wt. (Kg)	Body Capacity (Cu m)	Operating Range (short/ medium /long)	Loading Speed(short/ medium/fast)	Labour Requirement	Capital Cost Per Volume of waste collected	Running cost	Economic life of vehicle	Manoeuvrability	Suitable for local body Manufacture
Semi-Compaction Systems										
Fore & Aft. Tipper & Press Plate	9 000	10	Long	Fast	Low	Medium	Medium	Short	Medium	Yes
Side Loading Moving Barrier	9 000	10	Long	Slow	Medium	Medium	Medium	Short	Medium	Yes
Compaction Systems										
Rear Loading	14 000	10	Long	Fast	Low	High	High	Short	Poor	No
Hydraulic side-loading	14 000	10	Long	Fast	Low	High	High	Short	Poor	No
Hydraulic rotating compactor	14 000	10	Long	Fast	Low	High	High	Short	Poor	No

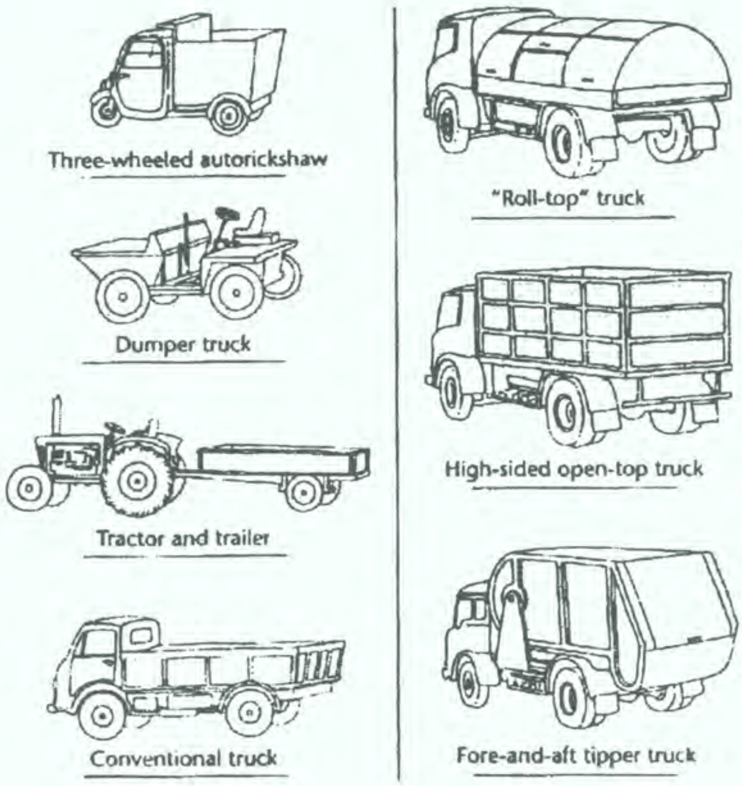
Table III - Characteristics of the main Waste Types of Collection Vehicles

Source: Refuse collection Vehicles for Developing Countries, UN (HABITAT)

Criteria for the selection of collection vehicles

The following criteria may be used when selecting collection vehicles in IMA- SIDS:

- *Select vehicles that use the minimum amount of energy and technical complexity necessary to collect the targeted materials efficiently.* Given the high energy costs and relative lack of technical backup on most SIDS, a trade off between relative cost of capital and labour is needed.
- *Choose locally made equipment, traditional vehicle design, and local expertise whenever possible.* There is a long history of vehicles being provided by international aid agencies which are not appropriate for their application, rust in the harsh environment, and cannot be fixed when they break down due to lack of parts or local expertise.
- *Select equipment that can be locally serviced and repaired, and for which spare parts are available.* This is critical in SIDS of the IMA to ensure ongoing utilisation from capital investment in the vehicles.
- *Choose muscle- and animal-powered or light mechanical vehicles in crowded or hilly areas or informal settlements, where access by larger vehicles is not possible.* These types of vehicle are significantly less capital intensive, easy to maintain, and have less impact on the environment, however use more labour, and may be perceived as old fashioned.
- *Choose non-compactor trucks, wagons, tractors, dump trucks, or vans, where population is dispersed, or waste is already dense.* These vehicles are lighter, easier to maintain, and offer lower capital costs but higher labour requirements. Waste collected in the majority of IMA SIDS is already at a high density, with high proportions of organic waste, therefore compaction in most cases is not necessary.
- *Consider the advantages of hybrid systems.* Where there is a significant difference between the urban and rural areas, or within a compact urban area, a hybrid system with two or more types of collection vehicle could be used. eg combining small muscle powered carts for collecting down narrow side streets and alleyways which then deliver back to a larger truck or wagon which moves slowly along the main street.
- *Consider compactor trucks in industrialised urban areas where roads are paved, and waste is not too dense or wet.* Compaction is often seen as more efficient, however, due to the typically high organic content and therefore high density of waste collected in SIDS, compaction does not significantly reduce the volume of waste collected. These trucks require more maintenance, and are not fuel efficient.
- *Select dual collection vehicles to enable simultaneous collection of both organics and recyclables within separate compartments.* Where waste separation is a priority, this collection method avoids the need for duplicating the collection runs for different separated materials.
- *If collection of waste will only take up one or two days per week, select a machine that can be utilised for other activities during the remainder of the week such as a tractor or tip truck.*



(Credit: UNCHS (Habitat))

2.2.4 Sound Practice in Street sweeping

The main factors that lead to the large quantities of litter that are observed in some of the towns and cities of the SIDS of the region are:

- improper clean up activities after public works;
- insufficient number and properly located bins;
- inefficient or non- existent storm drainage systems;
- spillages of waste set out for collection by waste pickers or animals ;
- spillage of collected waste during its transfer;

In a large number of the islands of the region, a large proportion of street wastes is generated as a result of deficiencies in the waste collection system.

The main objective of street sweeping should be the reduction of street litter. This can be achieved through

- an efficient collection system, regulation and education ;
- the design and use of effective tools and equipment

The manual methods for street sweeping are based on a street sweeping labourer equipped at varying levels with:

- brooms
- purpose designed or improvised sweeping brushes, and
- other cleaning tools

The UNEP International source Book recommends sound practice in manual sweeping systems under the following variations:

- Sweepers pick up and place their own sweepings in a cart. The carts then meet a collection vehicle at a pre-arranged time.
- Sweepers take their carts to small transfer stations located at the intersection of several sweeping routes.
- The wastes are put into containers and lined up for collection by a special truck.
- The sweepings are lined up in piles at the end of the route and collected later.

The main systems used to keep streets clean include the provision of litter bins, manual sweeping, mechanical sweeping and appropriate regulations.

Public areas such as central shopping areas, beaches, and outside small food shops must be provided with litter bins and public encouraged to make use them through education, and enforcement if necessary. These bins should be emptied regularly so that do not spill onto the street.

The mechanical methods available for street sweeping include:

- Highway vacuum street sweeping machines;
- Street washing machines;
- Towed rotary mechanical brooms;
- Pavement sweepers

Mechanical sweepers should only be used where these can be matched appropriately with the service areas.

In the majority of the SIDS, it is likely that manual sweeping will be preferred over mechanical sweeping as the mechanical sweepers require high capital, operation, and maintenance expenditure.

Manual pickup efficiency and health and safety can be optimised by providing sweepers with better uniforms, brooms, collector bins, and gloves.. (Credit: Chris Furedy).

2.3 Composting

In many SIDS, where there is limited or no space for landfilling, and where the soils are sandy, and poor in structure, the production of compost from organic waste would have a two fold benefit. Firstly, it reduces the volume of waste to be landfilled, and secondly, it provides a nutrient, and structural boost to the soils where it is applied.

Composting can be defined as the biological decomposition of complex animal, and vegetable materials into their constituent components. Composting occurs best when the ideal conditions are provided to enable bacteria and other organisms to break down the waste materials. This process can either be aerobic (with oxygen) or anaerobic (without oxygen), however, aerobic composting is most common.

For aerobic composting, the ideal conditions are for the waste to be broken into small particles. This is often done using a shredder. Aerobic bacteria require a mix of approximately one part nitrogen, to 30 -70 parts carbon food supply, and need 40% - 60% water in their environment and plenty of oxygen.

Separation and composting of organic materials for use as a soil conditioner, fertiliser or growth medium is common practice in many countries to a varying scale, and with varying success. Apart from the success stories, there are an alarming number of cases where composting systems have failed completely or operate at only 30% of their capacity. It is often the case in these situations that the composting technologies and or associated management systems installed are inappropriate for the area of application. It is therefore vital that the reasons for these failures are understood, and that sound practices are followed for identifying suitable technologies and management systems for composting in the IMA region SIDS.

2.3.1 Critical Lessons in Sound Composting Practice

The following sound composting practice guidelines have been developed, based on critical lessons learned from historical waste composting systems, which have failed, either completely or in part.

(a) *The materials to be composted must be compostable in order to produce a marketable product.*

- In most SIDS, the waste stream is already up to 50% organic, and therefore is ideal for composting.
- The compostable fraction of the waste stream can be enhanced by setting in place the appropriate collection and transfer systems, to ensure the compostable waste stream is kept separate.

(b) *Mechanical pre-processing of mixed solid waste does not work well enough in most cases, therefore source separation or manual separation of inorganic materials should be used.*

- In a technical sense, manual pre-processing of mixed waste, works best on small to medium scale systems for highly compostable waste streams
- A disadvantage of manual processing is that it may not be either pleasant or safe for workers.

(c) *Economic viability depends on three factors. Failure of any of these three can cause the system to fail.*

1. Unless composting has traditionally been performed, landfilling or dumping must be controlled and sufficiently expensive to make the moderate cost of composting (US $20-40/tonne) competitive with the cost of dumping. For many SIDS, the cost of land area, shipping of waste to centralised landfills, and environmental degradation due to landfilling should also be included in this assessment. Until these costs are fully recognised, it is unlikely that composting will be more cost effective than landfilling.

2. There must be a market or use for the compost, at the quality that it is produced. If this market or use does not produce a net income, the Government or Municipality should be prepared to cover the difference.

3. The waste stream composition has a large effect on the quality and marketability of the end product. Enhancement of the compostable waste stream by support of source separation, and materials recovery of non-compostables, is therefore needed.

(d) *Technical viability depends on three factors:*

1. There should not be dependence on mechanical pre-processing. This often breaks down.
2. The scale of the composting operation should not be too large.
3. The entire system from source separation to final screening must be designed as an integrated system, to deliver the appropriate inputs, and a high quality product output.

2.3.2 Sound Technologies for Composting

A range of technologies is available for composting, from small backyard to large scale regional systems. Moreover, largescale composting technologies are mainly of two types: windrow composting and aerated static pile.

A flow sheet has been drawn so as to evaluate composting technologies based on character and type of waste stream.

Furthermore, prior to selecting the proper technology, parameters such as particle size and nutrient content of waste needs to be determined. For example, in many cases, preprocessing equipment may be needed to shred or chip waste so as to reduce size and speed up composting.

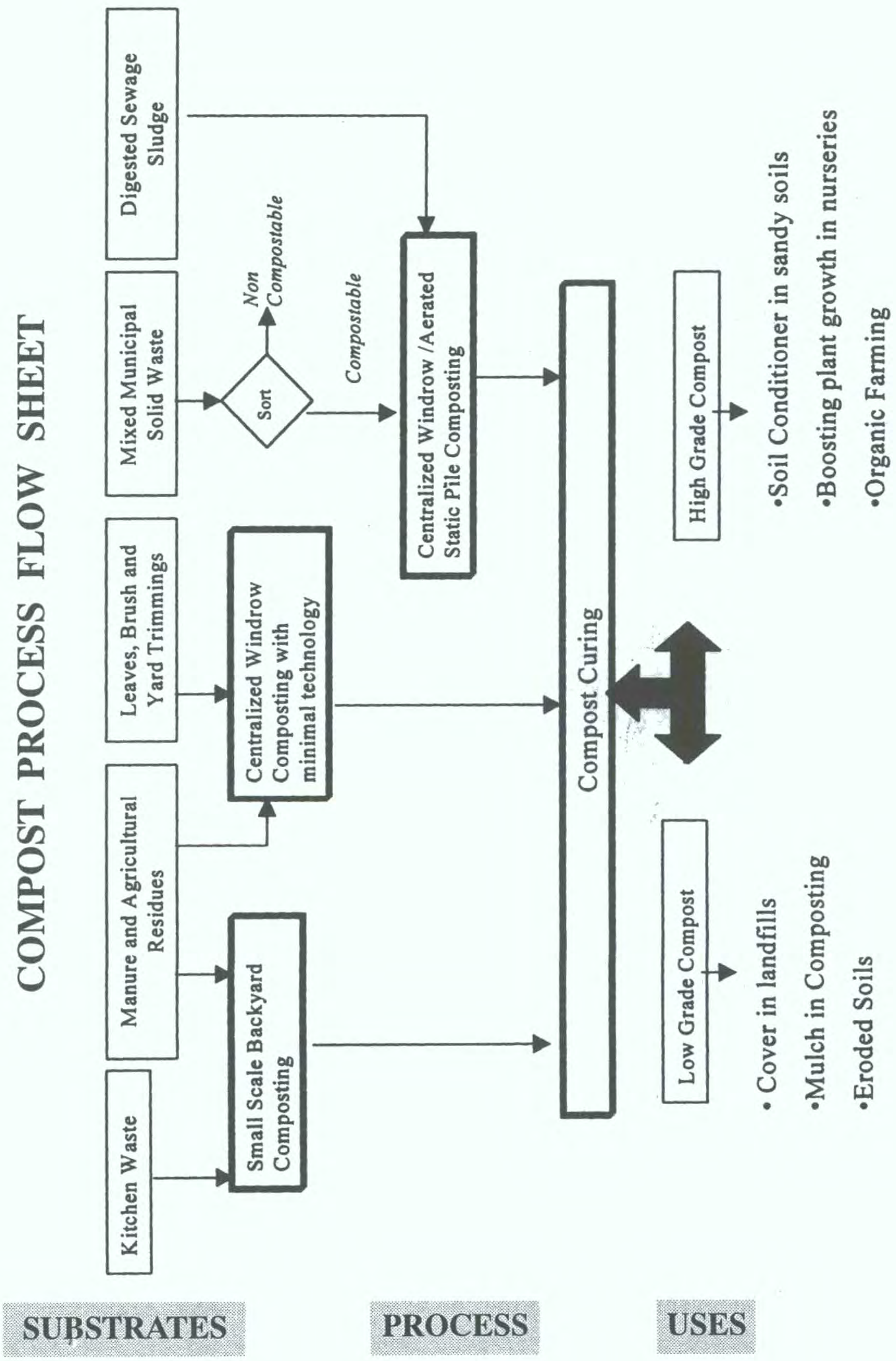
Also, the nutrient content of the wastes may not be appropriate for efficient composting, in which case different types of waste need to be blended for cocomposting. Below are such examples.

- Kitchen waste can be high in protein from meats, dairy products and some vegetables, leading to unpleasant odours. In this case, combination with high carbon wastes such as yard leaves, and lawn clippings, improves compostability

- The extent of animal feeding using kitchen waste should be accounted for. In many SIDS, pigs are kept to consume kitchen wastes, and provide meat, resulting in reduced quantities of waste being available for composting. Feeding waste to animals achieves a higher level of nutrient utilisation than composting, however, has associated health risks with animals transferring pathogens or diseases directly or via the water supply.

- Wastewater sludge can be composted, however, it is high in nitrogen and moisture. It must therefore be composted in combination with carbon sources such as wood chip, paper, and bulking agents to allow oxygen into the compost piles. Such practice requires health and safety precautions to avoid pathogen hazards.

Manure and animal waste are specific as they are generated on farms and can be composted using farm's equipment. This constitutes an important aspect of sustainable farming. Such wastes can easily be incorporated into community or larger scale composting systems.



Composting Technology:

Pre-processing Equipment

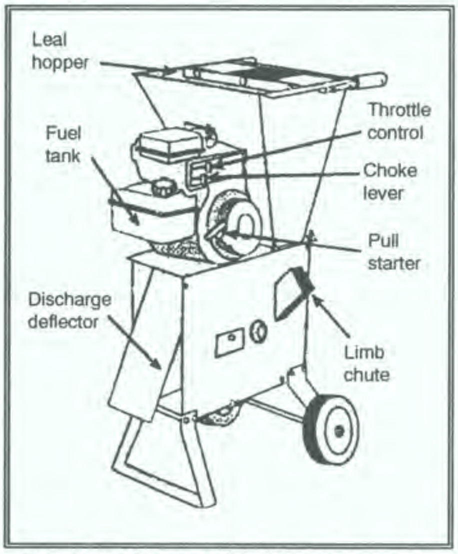


Figure 1. Diagram of a chipper-shredder.

Credit : University of Missouri.
Copyright 2000. University of Missouri.
Published by University Extension,
University of Missouri-Columbia.

Technology Description:

Done to reduce size of large organic wastes, and to blend wastes, to achieve the optimum composting environment.

Pre-processing equipment includes mechanical shredders, and chippers. This equipment is often costly, technically intensive, and vulnerable to break downs.

This Technology is a Sound approach when:

- there is a significant portion of hard to compost coconut husks, palm fronds
- Not generally considered sound practice if relied heavily on.

Extent of Use: Used in large scale composting plants. None used in IMA SIDS.

Operation and Maintenance:

- Operation and maintenance cost is high
- Easily break down

Advantages:

- Allows for optimum composting to be achieved,
- produces well blended, small size compost product

Disadvantages / constraints:

- costly
- high maintenance, and vulnerable to breakdown

Relative Cost:

- High initial - capital costs for machinery
- Ongoing - high operating and machinery maintenance costs

Cultural Acceptability

- No known cultural unacceptability.

Suitability

- On a community scale, a shredder, or chipper available for hire from the council by individual households to reduce the size of coconut husks, and palm branches may encourage composting

Composting system: <u>Small Scale</u>

Backyard Composting on Regional Scale

Credit : Adapted with permission from web site on compost bins (www.gardenaids.co.nz/tumblers.html)

Technology Description:

This is the smallest scale of composting. Composting in the back yard can be done informally, simply by creating a heap of compostable waste, or can be held using bricks, timber or an old drum.

Compostable waste such as kitchen scraps, paper, lawn clippings, and garden waste are all placed within the composting container. Once the container is full, a second is used or the first is shifted leaving the waste to break down over time to form compost. While the first pile breaks down, fresh waste is placed in the second container. The compost needs to be aerated by turning with a fork once a week, and water added if necessary to maintain the correct moisture content.

If encouraged on a regional scale, a municipality may issue standard compost bins and educational information which encourage backyard composting, make it tidier, and minimise the potential for problems to occur

Current Extent of Use:

- only on an informal basis by NGO's
- encouraged in some SIDS but not common in others

This Technology is a Sound approach when:

- a significant portion of households have individual or collective yards with enough room,
- composting is culturally familiar,
- the waste stream contains primary vegetable matter rather than animal matter

Operation and Maintenance: • relies only on some input by householders to monitor, water, and turn the compost to ensure good compost is made	
Advantages: • no collection, transfer and final marketing costs • low cost • encourages public involvement	**Disadvantages /constraints:** • can cause significant problems with high vermin populations • relies on public participation • less controlled
Relative Cost: • very low • costs for bins, and for education	**Cultural Acceptability:** • no known cultural unacceptability
Suitability: • Yes, where houses have sufficient yard space • Yes, where organic wastes are not otherwise fed to animals • Yes, because they are appropriate technology, and can be developed locally	

Composting Technology: Small Scale

Vermi Composting

Credit : Adapted from web site on vermicomposting (www.cuyahogaswd.org/verm.htm)

Technology Description:

Organic matter is broken down by worms in suitable containers such as plastic bins or wooden boxes which have plenty of airholes in the side and top.

A bedding material made of sawdust, peat, shredded leaves and/or soil is necessary.

At the beginning of the process, there is a need for special types of worms such as red wrigglers. Ordinary field worms are not suitable to decompose organic wastes. During the process, the worms will reproduce themselves.

This Technology is a Sound approach when:

- Availability of special types of worms
- Waste streams contain primarily vegetable matter

Extent of Use: On an informal basis in Madagascar

Operation and Maintenance:

- relies on some input by householders to control the process to ensure optimum conditions for the worms.

Advantages:

- The end product (Compost) is enriched by the presence of worm casts which render it more nutritious than regular compost
- No need to keep high temperatures

Disadvantages /constraints:

- Process must be carefully controlled
- Slower process compared to regular composting
- Need for a proper bedding material
- Worms may move away from compost pile.

Relative Cost:

- Very low
- Costs for bins, and for education

Cultural Acceptability:

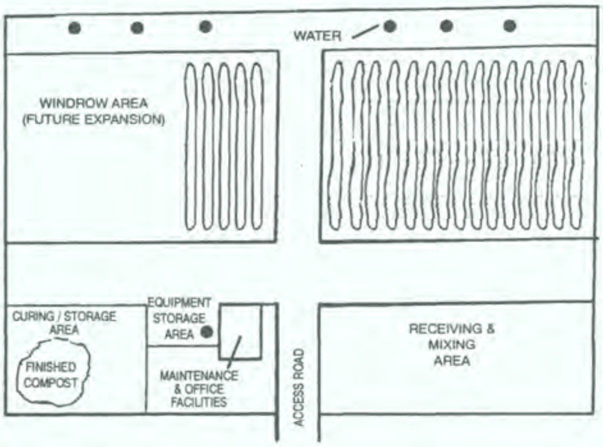
- No known culturally unacceptability

Suitability:

- Good for households with limited yard space
- Good for households when compost is not needed rapidly.

Composting Technology:

Windrow Composting



Windrow Compost Facility Layout
Note This site allows for access and movement of machinery throughout site. Where large machinery is not used this access is not required. (credit: UNEP; IETC Report 2)

Technology Description:

Windrowing, is a common method of composting, based on storing the organic waste in long rows. The windrows of waste form the basic environment for the waste to compost.

Windrow size is determined primarily from the climate, and waste composition. Other factors include the type of aeration used, and machinery used for aeration.

Windrows can be open, or covered depending on the climate and moisture content of the waste

Over time, the windrows of composting waste are aerated, turned and mixed as necessary to maintain the ideal composting conditions.

Aeration can either be done using manual or mechanical turning.

This Technology is a Sound approach when:

- The mechanical equipment used for handling and aerating the compost can be maintained using local expertise.

Extent of Use:

- windrowing is the most commonly used with mechanical aeration by turning rather than static aeration

Operation and Maintenance:

- Operation and maintenance needed for aeration machinery.

Advantages:

- Mechanical truning has lower capital costs, and machinery is not too specialised
- Static aeration requires less land area

Disadvantages / constraints:

- Mechanical truning requires higher landuse
- Static aeration has high capital cost
- Both have high maintenance, and vulnerable to breakdown

Relative Cost: medium

- Initial - capital costs for machinery
- Ongoing - operating and machinery maintenance costs

Cultural Acceptability:

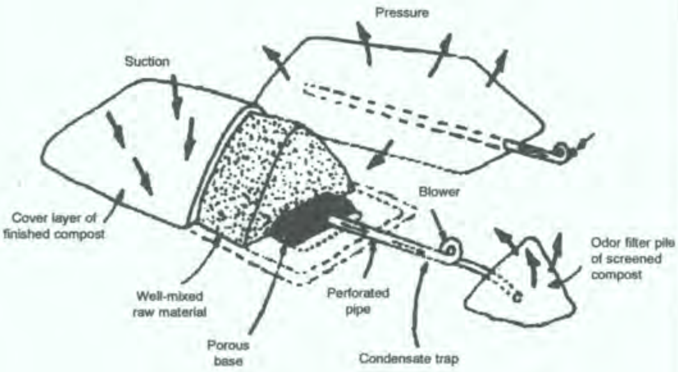
- No known cultural unacceptability

Suitability

- Windrowing using mechanical turning likely to be more suitable

Composting Technology:

Aerated Static Pile Composting



Aerated Static pile
Note: 2 ways for forced aeration: Blowing in air through the pile or sucking air from the pile.. (credit: On -Farm Composting Handbook, NRAES - 54, Rynk)

Technology Description:

Compost materials are arranged in piles similar to the windrow system. Air is introduced via a network of perforated piped within the compost pile. Air can be either forced in the pile or sucked out of the pile. Aeration machinery such as blowers are generally used.

Windrows can be open, or covered depending on the climate and moisture content of the waste

This Technology is a Sound approach when:

- Large volumes of compost are needed rapidly.
- Access area is small.
- Difficulties in having mechanical equipment for turning.
- Higher quality compost required.

Extent of Use:

- windrowing with aeration by turning is the most commonly used rather than the Aerated Static pile method

Operation and Maintenance:

- Operation and maintenance needed for aeration machinery.

Advantages:

- Static aeration requires less land area
- Finished compost obtained more rapidly

Disadvantages / constraints:

- Static aeration has high capital cost
- Both have high maintenance, and vulnerable to breakdown

Relative Cost: Very High

- Initial - capital costs for machinery
- Ongoing - operating and machinery maintenance costs

Cultural Acceptability:

- No known cultural unacceptability

Suitability

- Windrowing using mechanical turning likely to be more suitable

Composting System:

Centralised Composting of Green Waste on municipal Scale

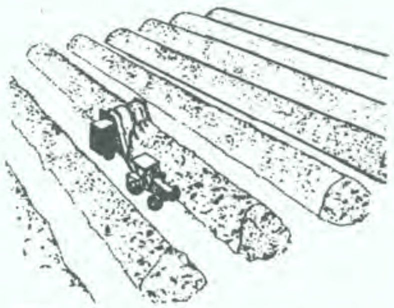


Figure 4.1
Windrow composting with an elevating face windrow turner

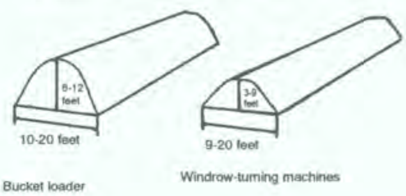


Figure 4.2
Typical windrow shapes and dimensions

Credit : Integrated Solid Waste Management by Tchobanoglous, Thielsen and Vigil (1998). Mc Graw Hill

Technology Description:

Quantities of 10 -100 tons per day.

The scale is such that waste requires transportation from the different source points within an urban city and or neighbouring towns, to a larger centralised site such as a transfer station.

Windrows may be used. Facility must come under the jurisdiction of the municipality, but could be privately operated. The site would have sufficient area to accommodate vehicles, compost turning, processing, screening, and storage. The site would need good signs and fencing instructing of acceptable wastes, current dumping area, and to keep unwanted.

Produces low quality compost suitable for landfill cover, or in agricultural and reserve land rather than as a sellable product.

This Technology is a Sound approach when:

- Technical and environmental assessments, engineering design, and formal evaluation of all issues involving all stakeholders is completed
- remediation and compensation to minimise nuisance effects of large scale composting
- separate collection and pre-process system of green wastes to ensure quality
- a formal system of using and marketing the Compost product is adopted

Extent of Use: Informal basis in Comoros Island (limited extent)

Operation and Maintenance:

- Operation and maintenance is high, with increased collection, transportation, and processing equipment needed.
- Level of maintenance depends on collection and processing technology adopted

Advantages:

- Good control from municipal Authority
- Economies of scale
- Low input required from individual households apart from separation of green wastes
- Appropriate for communities which have separate collection for green wastes

Disadvantages / constraints:

- Higher haulage costs,
- Requires large area of land
- Can cause problems with noise, vectors, and odours from large site

<table>
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Relative Cost: medium

- initial - site set up, vehicles, and for education
- ongoing -medium operating and machinery maintenance costs

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Cultural Acceptability

- may be land use issues for site chosen

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Suitability

- Yes, where town or city is of sufficient size. Therefore only potential in a few SIDS cities
- Yes, where there is insufficient space for smaller scale systems within the area
- Yes, where appropriate collection, and processing technology, can be developed and or maintained locally
- Yes, where a market is available for the compost

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Composting System: Large Scale

Composting of Mixed Wastes at Landfill or Incinerator Sites

(credit: UNEP- IETC : Directory of EST for waste management in Pacific SIDS)

Technology Description:

Quantities vary depending on source size. Manual sorting must be carried out at the landfill to separate biodegradables. Can be combined with a recovery facility for plastics and metals.

Semi-informal composting, where compostable materials are piled up to one side at the landfill using windrows or aerated static pile technologies.

Siting of composting plant is rolled into the landfill.

This Technology is a Sound approach when:

- other smaller scale forms of composting, or landfilling is not possible due to cost, land, or environmental factors.
- Alternative sites are limited,
- Financial or organisational structures are lacking
- Other composting technologies are not sound

Extent of Use: None used in IMA SIDS. In the future, may be used in Seychelles Islands

Operation and Maintenance:

- Operation and maintenance is low
- There may be some operation and maintenance for collection processes

Advantages:

- Low organisational and financial inputs required
- Site is combined with landfill

Disadvantages / constraints:

- Poorer quality compost produced
- Less control on environmental effects of process
- High costs

Relative Cost: High

- Initial - medium site set up, and for education
- Ongoing -High operating and machinery maintenance costs

Cultural Acceptability

- may be land use issues for site chosen

Suitability

- Yes, where financial, and organisational structures are lacking for more organised composting technologies
- Yes, where there is insufficient space for systems independent of landfill sites.

The following table summarises the various technologies used within the composting process.

Technologies used in the Composting Process	Potential use in SIDS	Description
Backyard Composters	High potential	To encourage backyard composting, municipalities may purchase or subsidise the purchase of compost makers for back yard use. Needs to be integrated with an intensive public education program
Pre-processing of waste materials	Minimal	-Often costly and technically intensive, vulnerable to breakdown. -Sound practice should minimise the need for pre-processing -Done to separate non-compostable waste, reduce size of large organic wastes, and to blend wastes, to achieve optimum composting environment
Windrow Systems	Most suitable	-The windrows of waste form the basic environment for the waste to compost. -Windrow size is determined primarily from the climate, and waste composition. Other factors include the type of aeration used, and machinery used for aeration. -Windrows can be open, or covered depending on the climate and moisture content of the waste
Active pile system	May be suitable	-Requires manual or mechanical turning of the windrows to aerate piles, provide blending of wastes, and prevent excess heat build up -require relatively high land use -has low capital cost and does not need specialised equipment or expertise. -specifically developed windrow turning machines require high capital and maintenance cost
Static Pile Systems	Limited Use	-Have higher capital costs than active pile systems -Windrows are not turned, but instead rely on air introduced via a network of perforated pipes within the compost pile. -require less area, but relies on mechanically pumped aeration
In-Vessel systems	Not suited	-expensive to build and operate -higher technology, and therefore more likely to break down.
Tower systems	Not suited	These systems are more expensive than windrowing, but composting is more rapid, resulting in an overall reduced land area requirement

Field Composting and using compost from dumps	Good potential	-largely informal practice where farmers mine organic waste and compost from dumps to provide enrichment to farm land. -has significant potential for health and safety problems, due to glass, or contaminants within the waste.
Vermiculture or vermicomposting or worm farming	May be suitable for small scale	-a relatively cool but aerobic process by which worms mechanically and biochemically break down organic matter by eating and digesting it. -requires considerable labour, and careful control of composting conditions. -not tested significantly on large scale
Anaerobic Digestion	Not suited	-high capital and technical inputs required. Therefore suited only to industrialised countries

2.3.3 Sound Marketing Approaches for Composting

The role of compost is often (mistakenly) compared directly to that of fertiliser. While compost does have some nutrient value, the most significant value is in conditioning of soils. Compost added to clay or sandy soil significantly increases moisture retention, synthetic and natural nutrient retention, is useful for temperature regulation, preventing erosion, and even reducing the incidence of some destructive agricultural diseases.

Sound practice for compost marketing should therefore provide education on the benefits of compost. Methods for such education and marketing include:

- Specifying use of compost in public works and government funded programs
- Subsidise the price of compost for sale
- Remove or modify subsidies on chemical fertilisers
- Give high profile coverage to business or public applications where the benefits of composting has been proven
- Encourage high quality compost production

In cases where there is very little suitable material for covering landfill wastes such as on many SIDS atolls, excess, or poor quality compost provides an excellent cover material, which can then support vegetation growth. For the atolls where soil materials are very scarce, this would be a very sound practice.

2.3.4 Environmental Impacts of Composting Technology

Apart from the positive impacts from composting, there are also negative impacts. These can include production of odours, carbon dioxide and other green house gases, air emissions from mechanical equipment, and leachate production if the process is not properly controlled.

Leachate contains high BOD, and surface runoff. It should be allowed to soak into the underlying soil, or captured and treated through a sand filter before being discharged to ground, or water. The moisture content of the wastes have to be monitored properly to avoid production of leachate.

2.3.5 Conclusions

There are a wide variety of scales, and methods available for composting. Despite a significant number of failed composting facilities, there is now sufficient information to enable proper evaluation of what is appropriate (if at all) in any specific situation.

The major factors to be considered for composting are; siting, input waste stream composition, selection of appropriate composting technology, the scale of composting, market development, and lastly what existing composting practices are.

In SIDS, composting has not been a way of life for residents, however, with increasing pressures on landfill space, unavailable cover materials, high percentage of biodegradables in the waste stream and waste problems in general, combined with appropriate marketing and education by municipalities, composting could become a significant and environmentally sound waste management technology in the IMA Region.

2.4 Incineration of Municipal Solid Waste

Incineration, (or burning) of Municipal Solid Waste (MSW) may offer an alternative to other forms of disposal when land suitable for landfilling is scarce. Incineration of Municipal Solid Waste substantially reduces the weight (up to 75%) and volume (up to 90%) of waste needing disposal into landfills. In addition, incineration can provide energy for heating or electricity, and destroys bacteria and viruses.

So why isn't incineration used more widely? Unfortunately, the benefits of incineration are most often out weighed by the significant capital and operating costs, potential environmental impacts, and technical difficulties of operating an incinerator.

In particular, the production and venting of such hazardous substances as dioxins from incinerators is a significant concern. Dioxins are very deleterious to health and the environment, and can be produced if incineration is not performed at temperatures above 850 degrees celsius (WHO Fact sheet 1999).

2.4.1 Sound Practice for Choosing Incineration Technology

In assessing the suitability of incineration as a technology for solid waste management, a majority of the following factors should be true:

- ***Suitable land for landfilling should be scarce***, making incineration cost effective,
- ***Installation and maintenance of all necessary environmental controls*** should be included with the incineration technology
- ***Size and position of the facility*** should be done to fit in with the other components of the MSWM system.
- ***Full and clean combustion of wastes is required*** through having sufficient energy content in the waste material to achieve the required burn temperature. (this may require the addition of an alternative fuel such as oil wood, or coal)
- ***A suitable nearby energy market*** is needed to utilise the energy produced

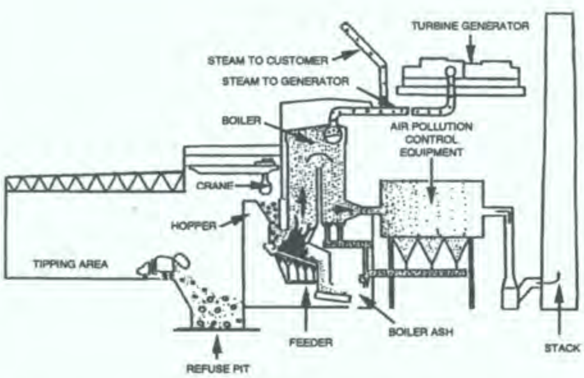
Four different incineration technologies are described in the following tables. These systems are:

1. Mass Burn Incinerators
2. Modular Incinerators
3. Fluidised Bed Incinerators
4. Refuse Derived Fuel (RDF) Technology

Apart form these dedicated solid waste incinerators, a certain quantity of municipal solid waste could be burned in existing oil, or new combined fuel electricity generators. Many SIDS already have oil powered generators which may be able to be adapted in some cases to take some waste, such as hazardous hospital wastes. This is looked at in more detail in the section on hazardous wastes.

Incineration Technology

Mass Burn Incinerators



Cross Section of Typical Mass Burn Facility (credit: UNEP; IETC Report 2).

Technology Description:

This is the predominant form of MSW incineration used.
Mass burn systems, generally consist of either two or three incineration units ranging in capacity from 50 to 1000 tons per day. (i.e. 100 - 3,000 t/day total capacity).

They can accept refuse that has undergone little pre-processing other than removal of over sized items.

Waste is deposited on a floor or pit before being continuously fed to a moving grate system which moves the waste through a combustion chamber

Although versatile, the mass burn system still requires that household hazardous wastes (certain cleaners, and pesticides) are removed to ensure environmental pollution does not occur, and that scrap metals are removed for recycling and reuse.

This Technology is a Sound approach when:

- Alternative landfilling area is scarce
- Necessary environmental controls can be set and maintained
- A high level of expertise, for operation and maintenance is retained
- Temperatures are maintained above 850 deg. C.

Extent of Use: None used in IMA SIDS.

Operation and Maintenance:

- high levels of operation and maintenance are needed for incinerators. If maintenance of environmental controls is not kept up to date, significant human and environmental impacts occur due to air pollution.

Advantages: (over other incineration technology)

- refuse requires little pre-processing,
- reasonably convenient and flexible in what they will burn
- commonly used in developed countries

Disadvantages / constraints:

- high cost
- high level of operation and maintenance required
- possible adverse environmental impacts

Relative Cost:

- Expensive

Cultural Acceptability:

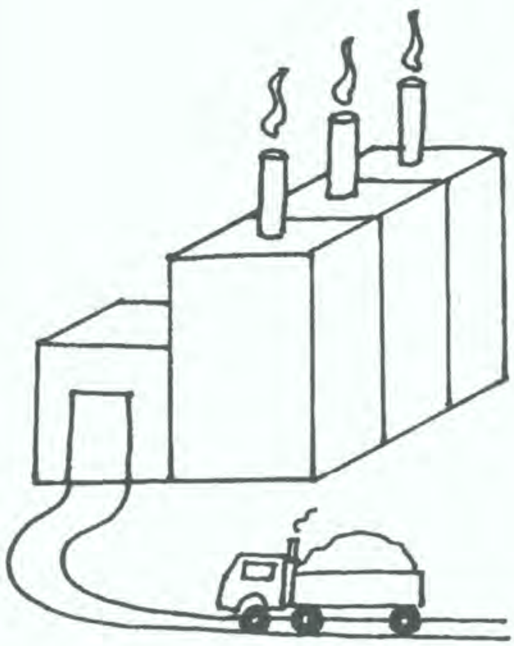
- No known cultural unacceptability

Suitability:

- only where landfilling area is scarce, and
- where a high level of expertise, for operation and maintenance is available

Incineration Technology:

Modular Incinerators



(credit: UNEP- IETC : Directory of EST for waste management in Pacific SIDS)

Technology Description:

Modular incinerator units are usually prefabricated units, with a smaller capacity of between 5 and 120 tons/day. Between 1 and 4 modules are typically operated together to provide up to 400 tons capacity in total, generally supplying steam for heating or electricity.

Modules can be operated continuously, or in a batch cycle depending on the quantities of waste to be burned.

- Operate using two combustion chambers. Gases generated in the primary chamber flow to an afterburner chamber, ensuring more complete combustion. Waste is deposited on a floor or pit before being continuously fed to a moving grate system which moves the waste through the primary combustion chamber.

Although versatile, the modular system still requires that household hazardous wastes (certain cleaners, and pesticides), are removed to ensure environmental pollution does not occur, and that scrap metals are removed for recycling and reuse.

This Technology is a Sound approach when:

- Alternative landfilling area is scarce
- Necessary environmental controls can be set and maintained
- A high level of expertise, for operation and maintenance is retained
- The quantities of waste to be burned is smaller

Extent of Use:

- None used in IMA SIDS but may suit smaller communities. Can be convenient for airport wastes.

Operation and Maintenance:

- high levels of operation and maintenance are needed for incinerators. If maintenance of environmental controls is not kept up to date, significant human and environmental impacts occur due to air pollution.

Advantages: (over other incineration technology)

- ideal for smaller communities
- modular units enable matching of demand
- can be operated on continuous or batch basis

Disadvantages /constraints:

- air pollution controls have been found to be inadequate, and inconsistent in some cases
- high level of operation and maintenance

Relative Cost: medium	**Cultural Acceptability**
• Less Expensive than other MSW incinerator options	• No known cultural unacceptability.

Suitability

- only where landfilling area is scarce, and
- where a high level of expertise, for operation and maintenance is available
- in smaller sized communities or Islands

Incineration Technology:

Fluidised-Bed Incinerators

An Incinerator in Gibraltar (Credit: Warmer Bulletin)

Technology Description:

Fluidised-bed incineration has been used most extensively in Japan, where plants are typically between 50 to 150 tons per day.

In the fluidised-bed system, the stoker grate is replaced by a bed of limestone, or sand, which behaves like a fluid as air is pumped through it in the high temperatures.

Unlike the other MSW incinerators, the fluidised-bed system required front end pre-processing of waste where glass and metals are removed, and the waste size is reduced.

Fluidised-bed systems operate successfully burning wastes of wide ranging moisture and heat content. Therefore high energy wastes such as paper and wood can be taken out of the waste stream for re-cycling and reuse. The Fluidised-bed system is therefore more compatible with high recovery recycling systems, where glass, metal, paper, and wood are all removed prior to incineration of the residual waste.

This Technology is a Sound approach when:

- Alternative landfilling area is scarce
- Necessary environmental controls can be set and maintained
- A high level of expertise, for operation and maintenance is retained
- The quantities of waste to be burned is smaller

Extent of Use:

- Used in Japan and some European countries but none in IMA SIDS.

Operation and Maintenance:

- high levels of operation and maintenance are needed for incinerators. If maintenance of environmental controls is not kept up to date, significant human and environmental impacts occur due to air pollution.

Advantages: (over other incineration technology)

- More efficient on smaller scale than mass burners
- Better control giving less residual ash & less pollution
- More compatible with high recovery/ re-cycling approach to MSWM

Disadvantages /constraints:

- Relatively new technology, not yet fully proven
- Requires more pre-processing of waste

Relative Cost:

- Expensive, savings over other systems inconclusive
- Likely to have lower maintenance costs

Cultural Acceptability

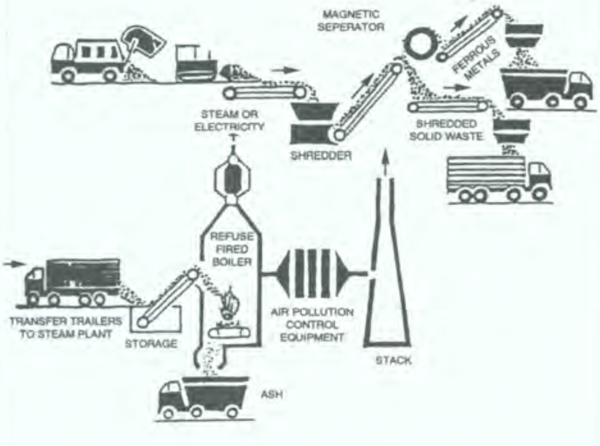
- No known cultural unacceptability.

Suitability

- only where landfilling area is scarce, and
- where a high level of expertise, for operation and maintenance is available

Incineration Technology:

Refuse-Derived Fuel (RDF)



Cross-section of a typical RDF Facility showing pre-processing, incineration, and air pollution control. (credit: UNEP IETC Report 2)

Technology Description:

Refuse Derived Fuel (RDF) can be described in a broad sense as any form of solid waste that is used as a fuel.

RDF is more often used to describe solid waste that has been mechanically pre-processed to produce storable, transportable, and more homogeneous fuel for combustion.

RDF can be divided into production and incineration components.

The level of complexity of pre-processing has increased the cost of RDF incineration systems to beyond that of mass burner systems.

RDF pre-processing involves a tipping floor and conveyors, where waste is sorted, screened, trommelled, shredded, hammer-milled, and palletised as necessary to suit the waste type, and final use specifications

This Technology is a Sound approach when:

- Alternative landfilling area is scarce
- Necessary environmental controls can be set and maintained
- A high level of expertise, for operation and maintenance is retained

Extent of Use:

- None used in IMA SIDS, Can be appropriate for incineration of MSW and coal to substitute incineration of bagasse during intercrop season in sugar producing SIDS

Operation and Maintenance:

- High levels of operation and maintenance are needed for pre-treatment and incinerators. High dependence on mechanical equipment can cause problems with breakdowns. If maintenance of environmental controls is not kept up to date, significant human and environmental impacts occur d due to air pollution.

Advantages: (over other incineration technology)

- More compatible with high recovery/ recycling approach to MSWM
- Ensures good removal of recyclables, and contaminants
- RDF can be used in a variety of burning applications

Disadvantages /constraints:

- Dependent on high mechanical inputs

Relative Cost:

- More expensive, due to higher level of pre-processing
- Likely to have higher pre-processing maintenance costs

Cultural Acceptability

- No known cultural unacceptability.

Suitability

- only where landfilling area is scarce, and
- where a high level of expertise, for operation and maintenance is available

2.4.2 Environmental Impacts from Incineration Technology

Air emissions and residual ash provide the major sources of pollution from incineration technologies. Air emissions and ash are the two main by-products from any incineration technology. If these by-products are not controlled appropriately, significant environmental impacts are possible.

Residual ash is derived from under the incinerator (bottom ash), and from particulate materials captured from exhaust gases (fly ash). These ashes contain high concentrations of contaminants, and therefore require careful landfilling to ensure these contaminants do not leach out, polluting ground and surface waters. Ash is landfilled in separate ash cells within general purpose landfills, or is placed in purpose built ashfills adjacent to the incinerator site.

Air emissions if uncontrolled, contain high levels of contaminants such as dioxins which is a compound considered within the endocrine disrupters as they mimic the function of endocrine hormones. These affect people by direct inhalation, ingestion through eating exposed foods, or via contact with skin. The level of contaminants in air emissions can be significantly reduced using appropriate "scrubbers," however these require a high level of monitoring and maintenance to ensure continuous effective operation.

Such maintenance requires highly trained technicians, and a policy framework which will reliably support the need for necessary maintenance expenditure.

The significance of environmental effects also depends on the location of the incinerator relative to population centres, and on prevailing weather, and geographic conditions.

These issues, should be high on the list of factors taken into consideration when evaluating incineration as a waste disposal technology.

2.4.3 Conclusion

Overall, incineration technology requires a high level of technical input to install, operate and maintain, when operated in an environmentally sound manner. To date, the majority of sound incineration technology has only been possible in developed countries, where sufficient technical and financial support has been available. Although, there is a need for an alternative to landfilling on a number of SIDS islands, the suitability of incineration technology is doubted at this time due to the lack of technical and financial backup for such installations.

2.5 Landfills and Other Methods of Disposal on Land

In a well designed MSWM programme, all other waste management options should be considered before the disposal option to landfill is selected. Unfortunately in many cases, the landfill is the only MSWM option used especially when existing landfills already exist.

Disposal of wastes can be broadly divided into three general classifications:

(a) Open Dumps

(b) Controlled Dumps

(c) Sanitary Landfills

Although these three types of landfill could be identified as different points along a continuum, they help to demonstrate the differences that exist along this continuum.

2.5.1 Open Dumps

Open dumps are very common in IMA SIDS, where dumping of waste has developed in a hap hazard fashion as the need to dispose of non-biodegradable waste has increased.

The following are typical characteristics of the Open Dump:

- Poorly sited
- Unknown capacity
- No cell planning
- Little or no site preparation
- No leachate management
- No gas management
- Only occasional cover
- No compaction of waste
- No fence
- No record keeping, and
- Allows waste picking and trading

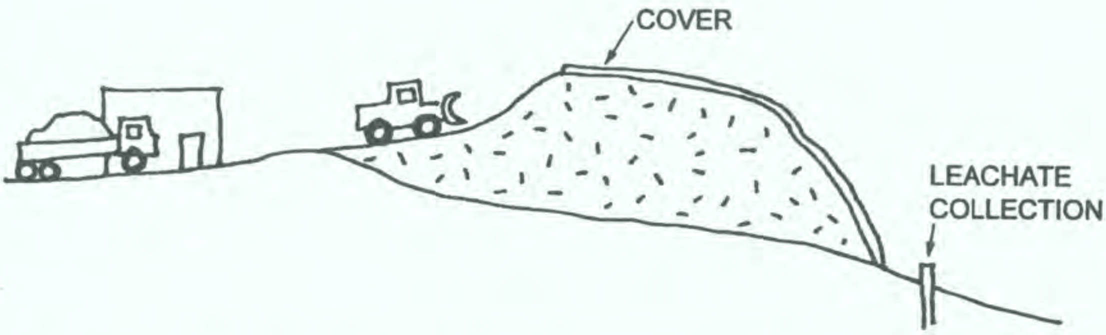
Unfortunately, in many cases, the development of anything more than an open dump has not been possible, due to technical, human resources and financial limitations. This is further compounded by a lack of public education regarding waste disposal, and a lack of planning, legislation and management frameworks to ensure better MSWM technologies are used.

Although common in SIDS, the majority of open dumps should not be considered as sound technology specially with the fragile ecosystems present in SIDS.

Open dump technology is not considered any further in this directory, however aspects of the landfill technologies that are considered can be applied to existing open dumps to make them more sound.

2.5.2 Landfill Technology Summaries

Landfill Technology: Controlled Dump

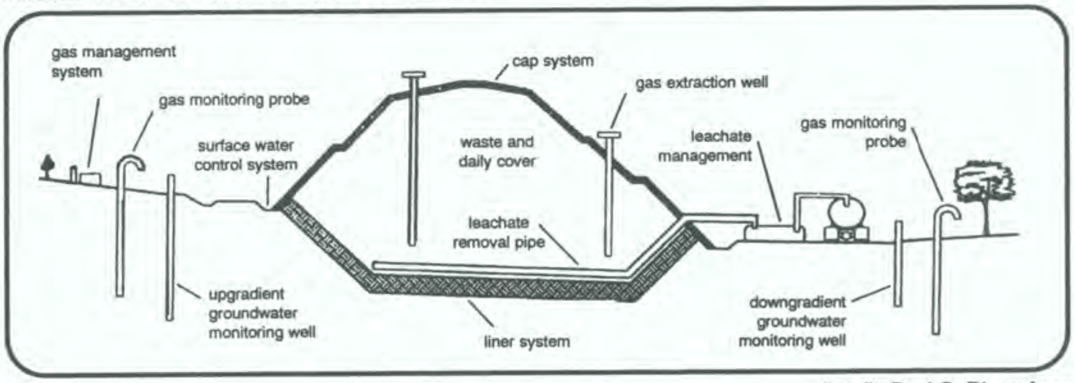


(credit: UNEP-IETC : Directory of EST for waste management in Pacific SIDS)

Technology Description: A controlled dump generally has the following characteristics: • Sited with respect to hydro-geology • Planned capacity • No cell planning • Grading and drainage in site preparation • Partial leachate management	• Partial or no gas management • Regular cover • Compaction in some cases • Fence • Basic record keeping • Controlled waste picking and trading
Extent of Use: • Limited use	
Operation and Maintenance: • requires a dedicated operator to ensure the management procedures above are carried out.	
Advantages: **(Over other landfill options)** • less risk of environmental contamination • permits long term planning • better rainfall runoff • extended lifetime • controlled access and use • good information • materials recovery by waste pickers allowable	**Disadvantages /constraints:** • may be less accessible • slower decomposition due to less moisture • increased costs, and maintenance • possible loss of materials recovery due to more controls over waste pickers
Relative Cost: • More expensive than open dumping, due to higher level of environmental protection • Higher operating costs due to compaction, covering, and other landfill management procedures listed above.	
Suitability: • Yes, for new sites, and existing open dumps where improvements can be made. • Where suitable sites are available.	

Landfill Technology : Sanitary Landfill

Typical schematic of a state-of-the-art landfill



(credit: Paul C. Rizzo Associates)

Technology Description:

A controlled dump generally has the following characteristics:

- Site chosen based on environmental risk assessment
- Planned capacity
- Designed cell development
- Extensive site preparation
- Full leachate management
- Full gas management
- Daily and final cover
- Compaction
- Fence and gate
- Record kept of waste volume, type, and source
- No waste picking and trading

Extent of Use:

Mauritius, Seychelles, Reunion.

Operation and Maintenance:

- requires a dedicated operator to ensure the management procedures above are carried out.

Advantages: (Over other landfill options)

- minimum risk of environmental contamination
- permits long term planning
- better rainfall runoff
- extended lifetime
- Secure access and use
- Reduced risk from site, gas, and leachate
- Good information
- risks to waste pickers eliminated

Disadvantages /constraints:

- may be less accessible, and longer siting process
- slower decomposition due to less moisture
- increased costs, operational and maintenance
- possible loss of materials recovery due to removal of waste pickers
- waste pickers displaced

Relative Cost:

- Most expensive technology, due to higher level of environmental protection
- Higher operating costs due to compaction, covering, and other landfill management procedures listed above.

Suitability:

- Yes, for new sites where the financial, management and technical resources are available for design and operation.
- Where suitable sites are available.

2.5.3 Sound Practices for Landfill Technology

In planning a new landfill, the following sound practices should be adopted. These sound practices should also be used as guidelines when evaluating existing landfills:

(a) Appropriate siting

(b) Leachate management and environmental impact minimisation

(c) Gas management and risk reduction

(d) Secure access and recording of waste inflow volumes and character

(e) Compaction and daily cover

(f) Documented operating procedures, and worker training and safety programmes

(g) Establishment and maintenance of good community relations

(h) Closure and post closure planning

Technologies for each of these sound practices are described in more detail in the following sections.

a) Siting

Siting of a landfill is the first and most difficult stage. When siting a landfill, the following considerations should be made:

- Capacity (determined from predicted waste quantities, and desired design life ideally 10-20 years)
- Public involvement (to ensure all issues and concerns are raised, and accounted for)
- Hydro-geology (Ideal clay and or impermeable rock will minimise the chance of leachate coming into contact with groundwater)
- Suitable cover material (needs to be available nearby in sufficient quality and quantity)
- Access (should be reasonably close to waste source if possible to minimise haulage costs, however environmental impact factors should be of higher priority in siting. Transfer stations are sound practice where landfills are too far away from the waste source)
- Proximity to Airports (as far away as possible to minimise bird strike)

In addition to the above, landfills should not be sited in very windy areas, near existing services such as drinking water ground or surface sources, reticulation, sewer, gas or electrical lines, or near residential areas, social venues, schools etc.

b) Leachate Management Technology

This is the key factor in safe landfill design and operation. Leachate is formed as rainfall soaks through the waste, and as the waste decomposes. The leachate drains to the bottom of the landfill, taking with it potentially toxic contaminants in soluble form. To minimise the potential for leachate to escape into the surrounding surface or ground waters, the following technologies are used:

- **An impermeable liner below the waste.** This can be either formed from in situ natural materials of clay of bedrock where these are of sufficiently low permeability (usually < 1 x 10-9 m/s), or be a constructed liner made from clay and/or synthetic materials. Modern liner designs combine natural soil layers and synthetic liners into a composite liner to utilise the best properties of both. Clay liners are thicker (typically 600 - 900 mm) and so more resistant to damage by sharp objects in the refuse. The clay can also act to absorb contaminants in the leachate. The synthetic plastic liners (eg 1-2 mm HDPE) are very impermeable but being thin are more susceptible to damage.

  Where natural clay soils are unavailable (eg on atolls or in volcanic country) the clay layer can be replaced with a synthetic layer of a GCL (Geosynthetic Clay Liner). A GCL is a manufactured liner combining bentonite powder and geofabrics into a thin but highly impermeable layer - a 10-12 mm GCL layer has the same seepage rate as a 600 mm clay layer. A GCL however does not have the same absorption capacity as a clay liner.

  Liner systems need effective protection by sand or geofabric layers to prevent damage from the overlying dainage layers and compacted refuse. Proper design of leachate drainage and collection systems is required to minimise the depth of leachate stored above the liners and so reduce any leakage to a minimum.

- **Minimise entry of rainfall** by capping of waste in controlled cells and placing a final capping liner when the landfill is completed. Rainfall infiltration can also be reduced by grading the landfill such that water drains off the surface. Where this is done, stormwater runoff should be captured in a pond and allowed to settle prior to discharge.

- **Leachate collection.** Leachate collected by a liner will accumulate and possible leak if it is not collected and removed using a collection system. Leachate can be collected by either placing a pump sump at the lowest point on the liner, or by grading the base of the landfill so that leachate flows by gravity out of the landfill. To increase drainage efficiency, perforated pipes, and or a coarse gravel layer is placed above the impermeable liner. Collected leachate is then discharged into a wastewater treatment system or ponds for treatment. Gravity drainage is the most sound if this is at all possible, as it avoids the need for pumping systems which have high maintenance costs, due to the corrosive nature of the leachate.

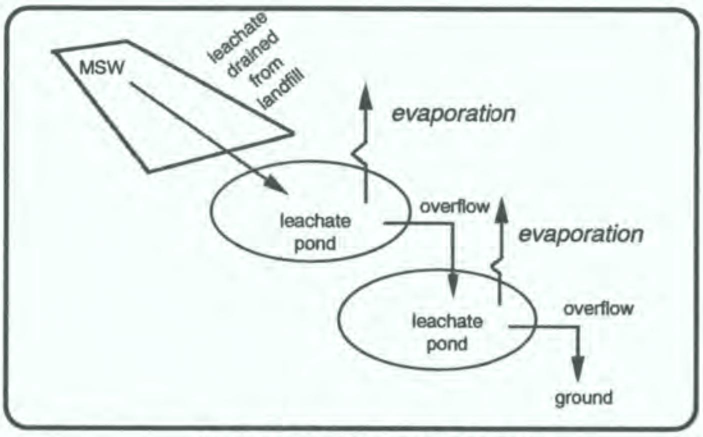
- **Leachate Re-circulation** is not really an option for the "disposal" of leachate, however it is effective at reducing the strength of leachate and so can make subsequent treatment steps easier. In a hot dry climate it may also be effective at reducing the overall volume of leachate requiring treatment and disposal through increased evaporation.

  Re-circulating of leachate over the waste in landfills has been shown to increase the production of methane gas, which is beneficial if the gas is being harnessed for energy. It also has the effect of accelerating decomposition of the landfill waste. Although leachate re-circulation is relatively new technology, it is a promising technology for managing leachate where landfills have suitable liners, and where gas collection for energy production is proposed. Re-circulation does increase the chance of leakage through the liner, clogging of the drainage system, and can cause increase odours.

- **Leachate treatment.** Leachate has usually very high BOD and COD and should not be discharged into any water course. It can be treated using biological, chemical and/or physical wastewaster treatment technologies to render it safe for discharge.

- **Grading of landfill base.** Where pre-drying is impractical, and there are no appropriate soils or rock for under liners, an increased grading of the landfill base, combined with a well distributed leachate collection system with reduce the quantity of leachate leaking into the underlying groundwater. This will add to the cost of the landfill, but may be cheaper than importing a suitable clay liner material at high cost.

Gravity collection and evaporation. Leachate drains by gravity to a lined waterproof pond down stream, where it is allowed to evaporate. A series of pond could be used as detailed below to allow evaporation and natural biological treatment. These ponds need to be sized based on a hydraulic balance of leachate, evaporation, and rainfall.



(Credit: UNEP; IETC TPS 6)

c) Gas management and risk reduction

Landfill gas is a mixture of methane and carbon dioxide produced by the decomposition of organic matter in the MSW. Landfill gas is highly flammable, and is heavier than air. It therefore tends to collect in hollows, and basements, causing a significant hazard through explosions, and displacement of air causing suffocation.

Where SIDS have open dumps, the generation of methane gas is likely to be minimal. In addition, any gases generated are likely to freely escape from the dump and be dispersed by sea breezes.

Where landfill gas is a problem, a low cost passive system to handle landfill gas consists of a number of buried vertical perforated pipes which use to natural pressure of the landfill gas to collect and vent or flare gas at the surface.

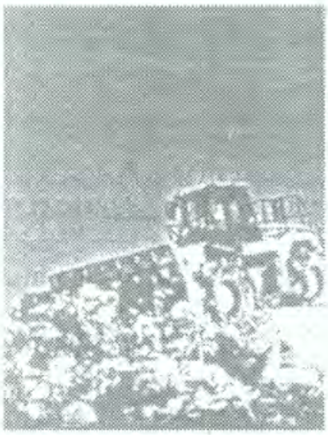
Alternatively, for a fully lined landfill, a more active system is to collect the gas using a network of pipes and pumps, and process it to use for heating or electricity generation. This is more risky, and required high technical input, therefore comes at a higher cost than the passive system.

d) Secure access and recording of waste inflow volumes and character

Fencing of landfills should be designed to restrict unauthorised access and to keep vermin and animals out. A vegetative hedge should be planted. This helps screen the landfill visually, and reduces wind nuisance.

A staffed gate should be at the point of entry.

e) Compaction and daily cover


(Credit: SPREP 1998)

Compaction of waste ensures that the maximum quantity of waste can be deposited in the designed landfill area, thus optimising the life of the landfill. However, full waste compaction requires the use of heavy mechanical compactors, which increases initial capital, and on going operation and maintenance costs. Therefore, where finance and technical inputs are not available, the use of specialised compaction machinery is not sound. However, a lesser extent of compaction may be possible using collection vehicles (e.g. Tractor and trailer, or a bulldozer).

Daily cover is used to prevent rubbish from being exposed where it can be blown by the wind, accessed by birds, flies, and rodents, and where it causes odours. Daily cover also helps aid the runoff of surface water during rainfall. Daily cover of waste is generally considered sound practice, however, where cover is not available and in cases where the waste does not attract flies and birds as has been reported in one open dump in Kiribati (Habitat 1994), it may be considered sound not to use daily cover material.

f) Documented Operating Procedures, and worker training and safety programmes

To ensure consistent and proper operation and management of the landfill over the life of the landfill (anywhere from 5 to 25 years or more), clear documentation of operating procedures is necessary. In addition worker training and safety programmes will ensure that the landfill is operated in an environmentally, and human safety friendly manner.

g) Establishment and maintenance of good community relations

One of the primary impacts from a landfill operation is the impact on direct neighbours, and on the local community. It is essential that good relations is established with these groups to ensure these impacts are understood, and dealt with before or as they arise. The level of community involvement can have a significant impact on the overall success of the landfill operation and the overall solid waste management strategy.

h) Closure and post closure planning

Once a landfill has been filled to capacity, a final layer of cover is necessary to seal the fill, and provide a final finish. The final levels, grade and finish need to be set according to the proposed after closure land use. Although a steep final surface grade will minimise the amount of rainfall infiltration and thus quantity of leachate produced, the proposed future landuse may require a flat surface, for example, a sealed carpark, recreation or sports field.

3.0 Hazardous wastes

Hazardous wastes are defined as waste materials that cause an immediate or cumulative hazardous potential to humans, and or the wider environment. These wastes could be toxic, poisonous, corrosive, flammable, infectious, or explosive. Hazardous wastes therefore need special handling, treatment, and disposal because of this hazardous potential.

As for other wastes, hazardous wastes should be managed using the same integrated waste management hierarchy. That being; waste minimisation, resource recovery, recycling, treatment, and final disposal.

The following is a list of different types of hazardous wastes found in IMA SIDS:

(a) Medical waste, (from hospitals, clinics, and laboratories)

(b) Sludge

(c) Industrial

(d) Used solvents from labs

(e) household and agricultural hazardous wastes, (e.g. oil-based paints, paint thinner, wood preservatives, herbicides, pesticides, cleaners, used motor oil, antifreeze, and batteries)

(f) used oils,

(g) batteries

(h) Asbestos

Effective management of the above hazardous wastes depends on a clear understanding of their potential for and mode of impact on human health and the environment. Once this impact is understood, appropriate management practice can be put in place for handling and disposing of the wastes.

3.1 Hazardous Waste Reduction

Hazardous wastes are generated from a wide range of industrial, commercial, agricultural and even domestic activities. These wastes may take the form of gases, effluents, liquids , sludges or solids. The potential for avoidance is heavily dependent on the processes involved and the nature of each activity. The first step in avoidance is to reduce at source the quantities of waste generated and their intrinsic hazards.

The means of effecting waste reduction at source are thus specific to the industrial processes that generate the waste.

Examples of waste reduction are:

- good housekeeping;
- substitution;
- process change;
- equipment change;
- reuse, recycling and recovery

It is recognized that some of above changes will take many years to implement in the islands , however some other measures are less expensive can be implemented immediately.

3.1.1 Good housekeeping

A proper inventory management, purchasing only the exact amounts of the chemicals and other materials required, is needed to prevent accumulation stocks of hazardous materials. All chemicals and products purchased should be reviewed and quantities kept to a minimum. Spills and waste avoidance opportunities can be identified through in house environmental audits. Attention should be given to minimising spills, leaks and contamination during the storage of raw materials, products and process wastes, and the transfer of these materials. Any spilled or leaked material should be collected for reuse.

3.1.2 Substitution

Waste reduction can also be achieved at source by substituting materials used in the process with less dangerous alternatives. This may involve additional cost, as the substitutes may cost more.

Some examples include the substitution of solvent based inks, dyestuffs and paints with water -based equivalents. Products using heavy metals such as cadmium, copper, chromium, nickel and lead can be replaced with those not containing these elements. Elimination of poly-chlorinated biphenyls (PCB) as transformer dielectric fluids (if in use).

3.1.3 Process Change

Techniques that can be applied to any manufacturing process include the following:

- ensuring that waste reduction is considered at the initial stages of all new projects and is made an integral part of the design;
- improving the efficiency of production processes by operating parameters or by modifying equipment to improve operational efficiency;
- evaluation of opportunities for material recycling or for the economic recovery and reuse of waste as a resource material or as a fuel substitute;
- utilization of a pre-treatment method to make disposal of the residue safer and cheaper.

3.1.4 Equipment Change

The changes of the process often include change of the equipment. For example, changing to a modern automatic pressure filtration can provide such advantages as the following:

- improved filtration efficiency ;
- improved purity of the filtrate;
- fewer washable chemicals in the filter cake;
- less wash water is generated, typically 1-3 times the mass of the filter cake.

3.1.5 Reuse, Recycling and Recovery

Reuse, recycling and recovery can be a cost effective alternative to treatment and disposal for some wastes and conserve resources. The potential barriers are:

- the ability a waste for material is often highly dependent upon "purity" of the waste.
- Failure to segregate wastes suitable for reuse, recycling or recovery can often result in an inability to recover or recycling those wastes.

Table IV -Wastes suitable for Re-use, Recycling or Recovery

Waste	Technology
Acids and Alkalis	■ Reuse by "down-grading i.e using for an application which requires a lower purity.
Solvents	■ Reuse by "down-grading i.e using for an application which requires a lower purity. ■ Solvent recovery (e.g Paint wastes using scraped surface evaporators). ■ Distillation of waste solvents. ■ Fractional distillation of solvent mixtures.
Oils	■ Reuse by "down-grading i.e using for an application which requires a lower purity. ■ Re- refining ■ Use as lower grade fuel.
Heavy Metals	■ Recovery by precipitation from solution and re-refining. ■ Electrolytic recovery of metal solution (e.g. electroplating solutions)
Precious Metals	■ Recovery by precipitation from solution and re-refining. ■ Electrolytic recovery of metal solution (e.g. electroplating solutions)
Etchants	■ Recovery of heavy metal (e.g. copper from copper etchants. ■ Regeneration of etchant

3.2 Treatment and Disposal

Treatment processes can be divided into the following main groups:

- Mechanical processing
- Physical/chemical treatment processes, and
- Thermal treatment processes,
- Landfill.

3.2.1 Mechanical Waste Processing

This is often used to prepare wastes from primary waste treatment processes such as physical / chemical treatment or thermal treatment.

For example, solid cyanide wastes may need breaking into small pieces before being dissolved for chemical treatment. Similarly, solid organic wastes need to be shredded and macerated and finally blended with other organic wastes prior to incineration.

3.2.2 Physical / Chemical Treatment Processes

It is the most common means by which inorganic hazardous wastes are treated. Some typical examples are as follows:

Table V -Common Physical / Chemical Treatment Processes

Process	Waste treated
Distillation	■ Used to separate liquids and also for the regeneration of organic solvents.
Evaporation	■ Used in process industry to concentrate waste solution for recovery of chemicals ■ Used as less costly option for liquid organic waste in cases where incineration cannot be afforded.
Sedimentation	■ Used for dewatering of sludges and slurries, especially when filtering is difficult.
Oxidation/Reduction	■ Oxidation of cyanide bearing wastes using chlorine or sodium ■ Reduction of hexavalent chromium wastes using ferrous wastes or sodium sulphite/ metabisuphite.
Neutralisation/ precipitation	■ Precipitation of heavy metals as hydroxides or sulphides from solution. ■ Neutralisation of acid and alkaline wastes
Hydrolysis	■ Alkaline hydrolysis of organo-phosphorous pesticides.
Flocculation, coagulation and filtration Electrolysis, electro-recovery etc.	■ Used for dewatering of partially treated sludges ■ Used for recovery of heavy metals and precious metals from solution (e.g gold electroplating solutions)
Stabilisation / Solidification	■ Used for both inorganic and organic constituents .

Physical /chemical treatment processes are simple and relatively low cost. They can be utilised at source or as "end-of- pipe"solutions .

Example of Physical treatment/disposal - Evaporation of liquid waste (organic)
This can take the form of a level concrete pad about 4 metres square with a 5 cm lip. The area can be covered with a thin layer of pebbles or clinker. Drain plugs should be included in the lip to enable rainwater to be removed. Disposal must be undertaken carefully, in good weather conditions and by a competent person. One batch of liquid waste must be allowed to evaporate before the next one is applied.

The person applying the solvent must be upwind and wearing protective clothing, footwear and gloves. Smoking should be forbidden in this area. The site should be fenced and downwind of any building.

Stabilisation is considered a key process, specially in islands where control of existing landfills and dumps are rather limited. Sludges or slurries very often contain heavy metal oxide and hydroxide . Under mild alkaline or acidic conditions, these constituents may leach . However, if these residues are stabilised the heavy metals will not leach.

Table VI- Examples of stabilised inorganic materials

Waste	**Method**	**Additional material**
Precipitated $Cr(OH)_3$ slurry from tanneries	Dewater, solidification in concrete mixer.	Poly-electrolyte, coal ash and Portland Cement
Cu^{2+} complex, concentrate from electroplating	If no cyanides present, precipitate CuS with Na_2S and solidify in concrete mixer.	Na_2S, FeCl3, coal ash, cement.
Cd^{2+} complex concentrate, or $Cd(OH)_2$ precipitate from electroplating	precipitate CuS with Na_2S and solidify in concrete mixer.	Na_2S, $FeCl_3$, coal ash, cement

3.2.3 Thermal treatment

Organic hazardous wastes may be treated either in dedicated hazardous waste incinerators or by destruction in other high temperature industrial processes. The most common example of the latter is the use of rotary cement kilns. Cement kilns are highly effective at destruction of organic hazardous waste.

Cement Kiln properties

- High temperature up to 2000° C
- Long residence time 4-6 seconds at 1800° C
- Good mixing
- Alkaline environment

The plant and equipment generally required for thermal treatment is expensive both in terms of capital costs and operating costs. For islands with limited resources the development of dedicated hazardous waste incineration capability is quite prohibitive. If cement kilns are operational on such islands they can play a key role in the disposal of these wastes.

3.3 Export of Hazardous Waste

Where hazardous wastes cannot be disposed of appropriately on an Island, they should be stored appropriately until such time they can be backloaded to be disposed in another suitable country or until appropriate recovery, treatment or disposal facilities are provided.

Suitable storage facilities should be:

- Secure from unauthorised access
- Weather proof to keep waste dry and prevent leaching to surface or groundwater
- Bunded to provide secondary containment where spillage or leakage does occur.

In considering options for export of hazardous wastes, this should be done in accordance with the Basel Convention. The *"Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal"* (March 1989), provides a detailed list of wastes which are hazardous. It also provides a general framework for sound management of hazardous wastes, and in particular the control and minimisation of movement of these wastes between different States, or boundaries.

3.4 Medical Waste

Medical waste required careful handling and disposal because it contains high levels of pathogenic or infectious waste, sharps, and harzadous or toxic substances such as cleaning agents, or discarded medications. In most of the IMA / SIDS, these wastes are often disposed of in a haphazard manner in open dumps, where they are not fully secured from access by the general public, or children playing in these areas.

It genarally refers to :

- human anatomical waste - human tissue, organs and body parts
- microbiology laboratory waste - lab cultures, stocks or specimens of microorganisms
- human blood and body fluid waste - items saturated or dripping with blood, body fluids contaminated with blood, and body fluids removed for diagnosis during surgery treatment
- waste sharps - needles, syringes, blades , or lab glass capable of causing punctures or cuts
- pharmaceutical waste
- liquid and chemical waste

This represents a small portion (typically 10 to 15 %) of the total volume of waste generated by health care facilities.

3.4.1 Segregation and Packaging

This type of waste must be segregated from the general waste stream. This is carried out through sorting at the point of generation. The segregated wastes must be safely contained during the handling and to the point of disposal. The packaging must remain intact throughout handling, storage, transportation and treatment.

- ***Source separation within the hospital to***

a) separate harmless waste such as paper, cardboard, and food scraps, for reuse and recycling,

b) isolates infectious and hazardous wastes using special collection containers which are colour coded, or clearly different for appropriate disposal.

CYLINDER-TYPE
WASTE CONTAINER
HALF-CUT OIL DRUM

CYLINDER-TYPE
PLASTIC WASTE CONTAINER

Source: WHO Webpage

The packaging must remain intact throughout handling, storage, transportation and treatment.

Sharps Containers

- sharps waste should be placed in puncture-resistant containers labelled with the words " *"Sharps Waste"* or with the international biohazard symbol and the word *"Biohazard."*
- sharps containers should be kept upright and should not be overfilled sharps containers.

Plastic Bags

Plastic bags should be provided for the storage of the wastes. Bagging is intended to prevent inadvertent exposure of personnel to infectious materials and to prevent contamination of the environment. A single bag would suffice if it is impervious and sturdy and if the article can be placed in the bag without contaminating the outside of the bag, otherwise double bagging should be used.

Table VII- Containment of Medical waste

Type of Waste	Colour of container[1]	Type of container
Infectious waste	red	Leak proof and strong plastic bag, or containers supporting autoclaving
Other infectious waste, pathological and anatomical waste	yellow	plastic bag or containers
Sharps	Yellow or red	Puncture-proof containers
Chemical and pharmaceutical	Brown	container

1) WHO recommendation, the use of other colour codes in a country is also possible

3.4.2 Treatment and Disposal

Medical waste should as far as possible be inactivated or rendered safe before disposal or discharge. The decision to treat the waste and choice of treatment method should be based on the following considerations:

- the type and nature of the waste material;
- the hazard and viability of the organisms;
- the efficiency of the treatment method;

The main chemical and physical methods for the treatment or inactivation of waste include:

- steam sterilization;
- chemical disinfection / sterilization;
- dry heat sterilization;
- irradiation (e.g with microwave, gamma and ultraviolet radiation)

Table VIII.- Example of treatment methods related to the type of waste

Type of waste / Treatment	**Liquid**	**Solid**
Thermal	Recommended	Recommended
Chemical	Appropriate	Appropriate
Irradiation	Possible	Possible
Incineration	Possible	Recommended
Filtration	Possible	Not applicable

The main advantages and drawbacks of some of the treatment and disposal options are shown in the table below.

Table IX: Advantages and Drawbacks of some of the Treatment and Disposal Options

Treatment / disposal methods	Advantages	Drawbacks
Chemical disinfection	Highly efficient disinfection good operating conditions. Costly if the chemical disinfectants are expensive.	Highly qualified technicians needed for operation. Use of hazardous chemicals which require comprehensive safety measures. Inadequate for pharmaceutical, chemical and some types infectious waste.
Microwave irradiation	Good disinfection efficiency under appropriate operational conditions;	High investment and operational costs; potential operation and maintenance problems.
Wet-thermal treatment	Relatively low investment and operation costs	Shredding are subjected to many breakdowns and bad functioning; Operation requires qualified technicians ; Inadequate for anatomical waste pharmaceutical and chemical waste.
Drum or brick incinerator	Drastic reduction of weight and volume of the waste ; very low investment and operating costs.	Only 99% destruction of micro-organisms; No destruction of many chemicals and pharmaceuticals; Massive emission of black smoke, flying ashes and toxic flue gas.
Single chamber icineration	Good disinfection efficiency; Drastic reduction of weight and volume of the waste ; The residues may be landfilled; No need of highly qualified operators; Relatively low investment and operation costs.	Generation of significant emission of atmosphere pollutants ; Not efficient in removing thermally resistant chemicals and drugs such as cytotoxics.
Pyrolytic incineration	Very high disinfection efficiency; Adequate for all infectious wastes, and most of pharmaceutical and chemical waste.	Relatively high costs of investment and operation.

WHO have significant resources available on handling and disposal of medical wastes. Their web site http://www.who.org is worth a visit, or information can be obtained from WHO, Geneva (e-mail: publications@who.ch).

3.5 Used oils

Used oils often end up in the sewer system, or are disposed of with other solid wastes, where they ultimately end up causing environmental damage.

Apart from used oil from automobiles, considerable waste oil is produced by electricity generators. For example, in Niue, the powerhouse produces 200 litres of waste oil every month (Habitat July 1998). This is just one of many fuel powered electricity generators used throughout the SIDS.

Another significant source of used oil is from electricity transformers. This oil has been reported to contain PCB's (SPREP Solid Waste Management).

The following sound practices are recommended for handling used oil:

- ***Oil providers, such as garages and shops, should be required to have storage drums*** where used oil can be returned free of charge for collection and appropriate reuse or disposal.
- ***Re-refining into lubricating oil.*** The residue resulting from re-refining should be disposed of appropriately by burning within, cement kiln, or within a permanently sealed container in a landfill.
- ***Use as a fuel in an incinerator or electricity generator or heater.*** In this case, there is a risk that heavy metals contained in the oil may be emitted into the environment. The most sound option for burning of used oil is in a cement kiln where metals are absorbed into the cement matrix.

3.6 Batteries

Old flat lead batteries from cars, trucks, and other uses contain acid and lead, both of which are hazardous. The following are sound practices for batteries :

- **Recycling in controlled environments.** Small scale uncontrolled recycling can often be highly polluting and hazardous.
- **Drainage of acid with subsequent neutralisation.**
- **Melting of the lead at a non-ferrous foundry for reuse as sinkers.** This can be considered as "unsound" and dangerous due to the production of hazardous fumes.
- **Export of batteries for re-cycling** (storage area required).

Small batteries contain nickel and Lithium. These batteries should also be collected separately from other waste and backloaded to suitable offshore countries for disposal.

4 Wastewater Treatment Technologies

4.1 Introduction

Wastewater treatment technology aims to reduce the strength of wastes making them suitable for reuse (e.g. land application) or for safe disposal into receiving water bodies. There are numerous technologies to deal with the treatment and disposal of wastewater throughout the world. Many of these technologies have been used in the IMA / SIDS region however, for many reasons they have failed.

These include:

1. Inappropriate design and technology: this may be due to a poor consultant being employed and/or an under appreciation of local considerations;
2. Lack of resources: this is often responsible for poor maintenance, and includes both a lack of material resources and, more importantly, inadequate human resources.
3. Inadequate regulation: inappropriate standards, lack of legislation and/or enforcement
4. Lack of incentive to keep the plant operating well: wastewater treatment facilities are often seen as a drain on resources as they do not generate revenue.

This section will focus on proven sound environmental technologies plus those currently used in the region, grouped under the following headings:

- Wastewater Collection and Transfer
- Wastewater Treatment (On-site)
- Wastewater Treatment (Centralised and Decentralised)
- Wastewater Reuse
- Wastewater Disposal Systems
- Industrial wastewater treatment systems
- Optimizing wastewater treatment

Suitable wastewater treatment and disposal technologies are already well documented and much of the following information has been taken from existing reputable sources again focusing on the IMA / SIDS region.

4.2 Wastewater Collection and Transfer

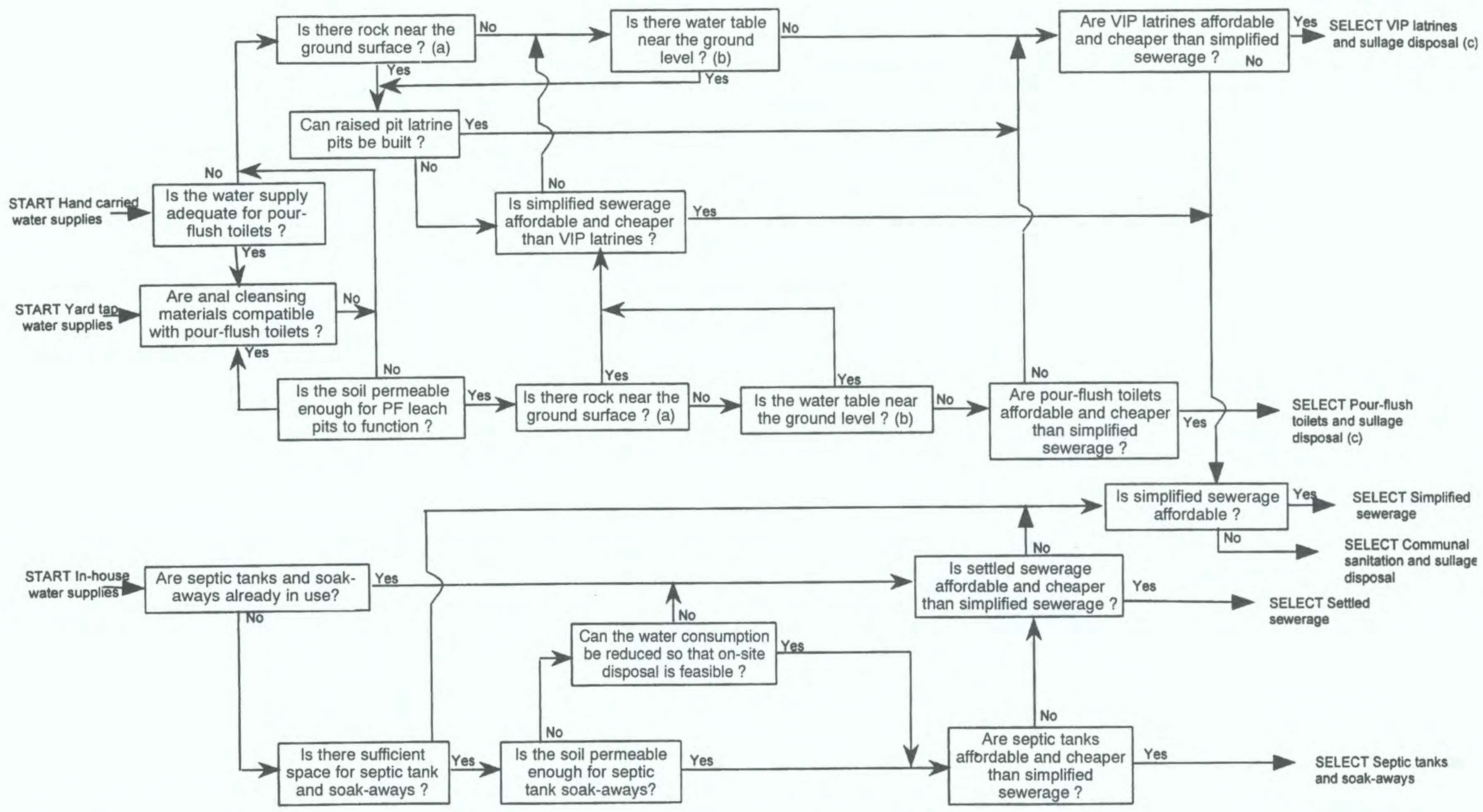
Waste collection and transfer for many on-site disposal methods is just a "direct drop" into a latrine pit or vault without using water for flushing. Some latrines have water seal devices to control insects and odours. Septic tanks and other types of latrines require some pipe work to receive waste as well as a water supply, when cistern or pour flush toilets are used. Good plumbing standards are important to ensure proper operation and no leaking pipes. Governments should ensure that plumbing standards are in place and enforced, normally through local building codes and permits that are required prior to the construction of a dwelling.

All but a few types of on-site disposal systems requires water to transfer waste throughout the treatment system. Thus the availability of a reliable water supply is a major criteria in selecting the type of wastewater disposal to be used.

Centralised and decentralised systems require reliable water supplies as well as reticulation networks to collect and convey to treatment plants and final disposal locations. These systems often require extensive pumping to transfer wastewater through the reticulation network. Again good plumbing standards are required within dwellings as well as good design criteria and construction practices for reticulation networks and pump stations to minimise potential operation and maintenance problems.

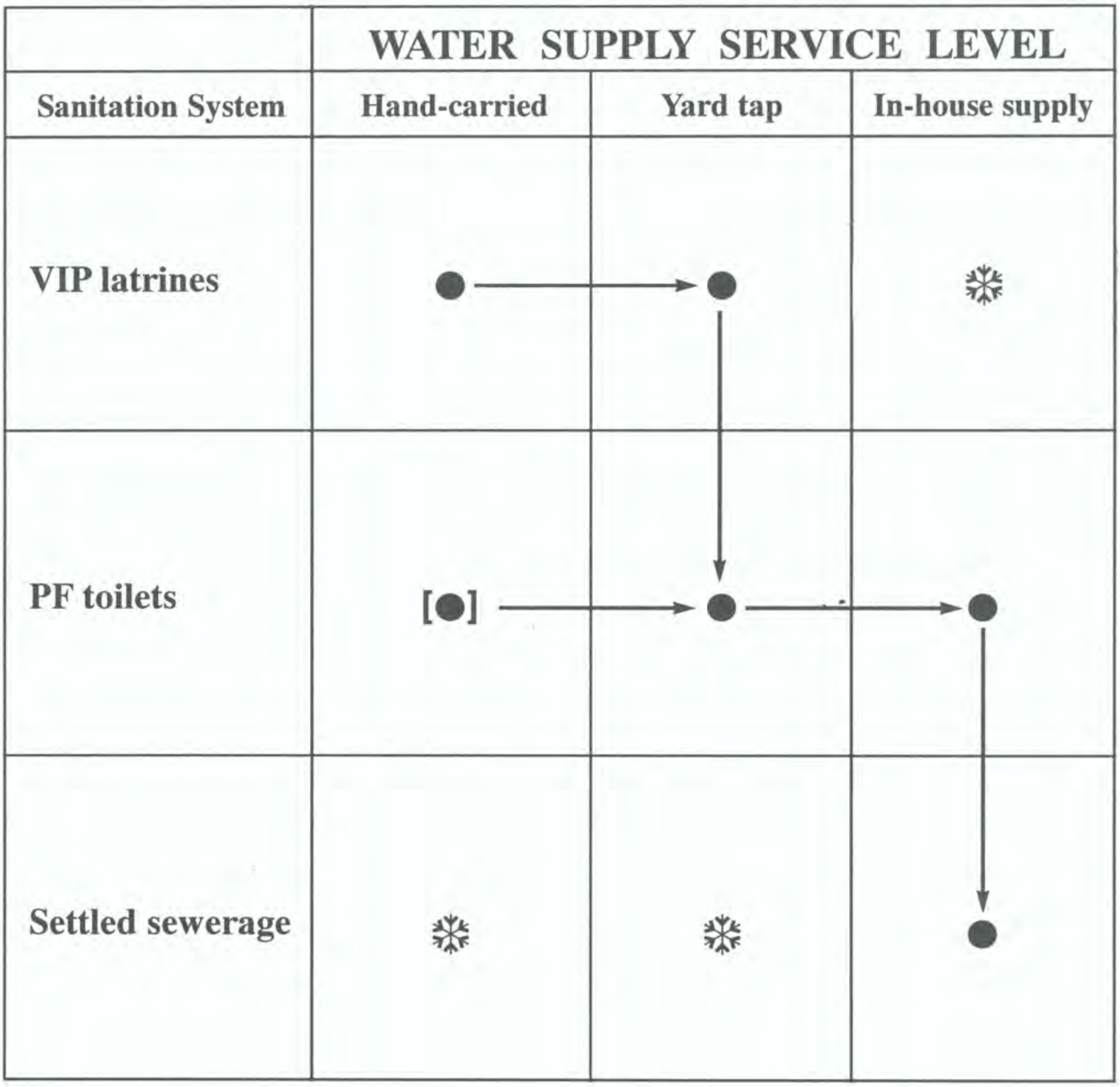
A sanitation technology algorithm is given in Figure 1. Sanitation upgrading can be done as part of a planned sanitation sequence, as shown in Figure 2.

Figure 1 : SANITATION TECHNOLOGY SELECTION ALGORITHM



Notes : (a) to < 1m; (b) to within 0.5 m either permanently or seasonally;(c) decide single pits and alternating twin pits (After Mara, D (1998)

Figure 2 : PLANNED SANITATION UPGRADING SEQUENCES ***(After Mara, D 1998)***



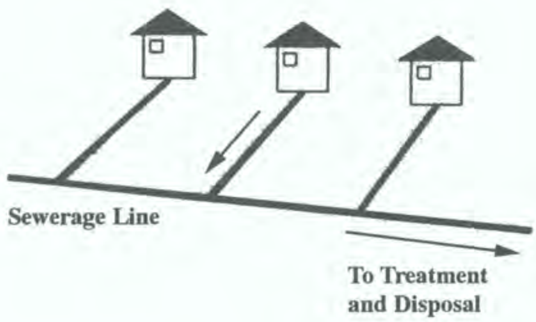
[●] Feasible if sufficient water carried home

❄ Combination unlikely

4.2.1 Sewerage Systems

Collection and Transfer Systems:

Conventional Sewerage



Source: T. Loetscher (1998)

Technology Description:

Household sewage is collected by an underground pipe system to treatment facilities or directly into receiving waters on land application.

Conventional sewerage consists of individual house connections to piped reticulation system. The reticulation systems normally include series pump stations to convey the sewage through system, especially on atoll and coastal communities due to flat topography and high groundwater levels. Manholes and other access chambers are required to maintain and clean reticulation systems.

Systems are normally based on conservative design criteria resulting in high capital construction and operational costs.

Current Extent of Use:

- Most major urban areas in the region.

Operation and Maintenance:

- High degree of operation and maintenance required especially if pumping is required
- Skilled personnel required

Advantages:

- no worries to household users
- provides good service to households
- promotes good hygiene practices.

Disadvantages /constraints:

- high capital and o & m costs
- high technology requiring skilled engineers, contractors and operators.
- ample and reliable piped water supply required
- adequate treatment and/or disposal required for a large point source discharge.

Relative Cost:

- high

Cultural Acceptability:

- is generally accepted within the region

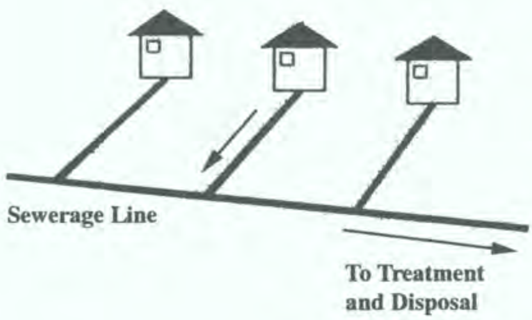
Suitability

- In urban areas that have the resources to implement, operate and maintain systems plus provide adequate treatment to avoid pollution as the discharge end.

Collection and Transfer Systems:

Simplified Sewerage

(smaller diameter pipes then conventional sewerage)



Source: T. Loetscher (1998)

Technology Description:

Similar to conventional sewerage systems, household sewage is collected by an underground pipe system to treatment facilities or directly into receiving waters or land application. However design criteria for construction are much less conservative allowing for minimum hydraulic requirements. This results in cost saving from:

- Smaller pipe diameters
- Flatter pipe gradients
- Shallow pipe depths
- Fewer access chambers
- Smaller pumps

Note that this type of collection system better suits the "settled sewerage" system where most solids are removed using an onsite septic tank before entering the small diameter reticulation system.

Current Extent of Use:

- Not often used within the region.

Operation and Maintenance:

- High degree of operation and maintenance required especially if pumping is required
- Skilled personnel required
- Higher blockage risk then conventional sewerage

Advantages:

- lower capital cost then conventional sewerage
- no worries to household users
- provides good service to households
- promotes good hygiene practices.

Disadvantages /constraints:

- smaller diameter pipes may result in a higher risk of blockages and thus increased maintenance.
- high technology requiring skilled engineers, contractors and operators.
- ample and reliable piped water supply required
- adequate treatment and/or disposal required for a large point source discharge.

Relative Cost:

- high but less them conventional sewerage

Cultural Acceptability:

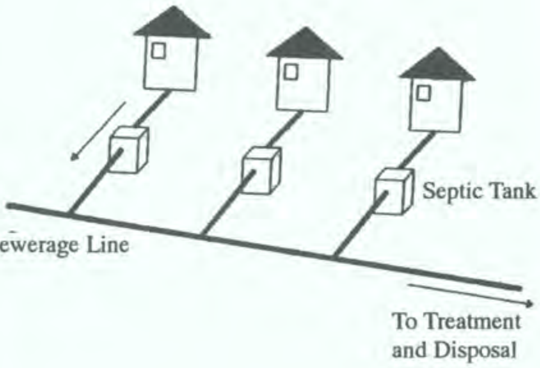
- Should be accepted within the region

Suitability

- In urban areas that have the resources to implement, operate and maintain systems plus provide adequate treatment to avoid pollution as the discharge end.

Collection and Transfer Systems:

Settle Sewerage



Source: T. Loetscher (1998)

Technology Description:

Similar to "conventional sewerage" systems where household sewage is collected by an underground pipe system to treatment facilities or directly into receiving waters or land application. However before the sewage enters the reticulation system, it enters a septic tank, where most settleable solids are removed, thus only the liquid effluent is reticulated.

Thus the resulting effluent is of "better" quality then if the septic tanks were not in place. However the septic tanks will require maintenance and cleaning.

In principle the design of the "settled" system is the same as "conventional" systems, however with solids removed from the system, pipelines may be smaller, similar to the design for the "simplified" system.

Current Extent of Use:

- Not often used in the region.

Operation and Maintenance:

- high degree of operation and maintenance required especially if pumping is required
- skilled personnel required
- maintenance and cleaning of septic tanks required

Advantages:

- no worries to household users except maintenance and cleaning of septic tanks
- provides good service to households
- promotes good hygiene practices.

Disadvantages /constraints:

- high capital and o & m costs
- high technology requiring skilled engineers, contractors and operators.
- ample and reliable piped water supply required
- adequate treatment and/or disposal required for a large point source discharge.

Relative Cost:

- high

Cultural Acceptability:

- Should be generally accepted within the region

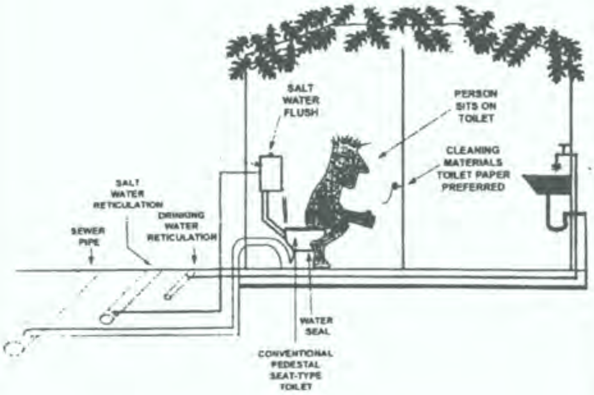
Suitability

- In urban areas that have the resources to implement, operate and maintain systems plus provide adequate treatment to avoid pollution as the discharge end.

Collection and Transfer Systems:

Saltwater Flushing

(Dual Distribution Systems)



Technology Description:

Dual distribution systems involve the use of water from two different sources and reticulated in two separated distribution networks. Potable water is distributed in one system for most domestic household uses while a second system reticulates non-potable water (ie salt or brackish water) for flushing toilets and conveying wastewater from households for treatment and/or disposal. Using this technology conserves limited freshwater resources. This type of technology would generally be used near the coast where seawater or brackish water is abundant. Saltwater systems require special consideration for the selection of materials due to corrosive nature of seawater. Pipes need to be colour-coded or have other identification to distinguish from freshwater reticulation pipes and to avoid possible cross connections.

Current Extent of Use:

- Not currently used in the region but can have applications in hotels near the coast

Operation and Maintenance:

- operation and maintenance similar to normal freshwater systems
- high degree of operation and maintenance required due to pumping requirements
- potential corrosion problems exist that may compound maintenance requirements.

Advantages:

- use of lesser quality waters for non-potable purpose reduces the use of limited freshwater resources.

Disadvantages /constraints:

- high capital and o & m costs
- high technology requiring skilled engineers, contractors and operators.
- Risk of polluting groundwater through leaks
- Risk of cross connections

Relative Cost:

- dual systems are expensive due to the duplication of distributions networks and the need to use corrosion resistant materials.

Cultural Acceptability:

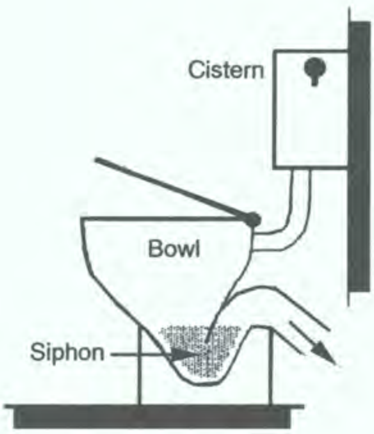
- is generally not well accepted within the region

Suitability

- In urban coastal areas that have limited freshwater resources.

Collection and Transfer Systems:

Cistern-Flush Toilet



Source: T. Loetscher (1998)

Technology Description:

The toilet bowl consists of a siphon, which provides a water seal against bad odours from the effluent pipe. Excreta are flushed away with water stored in the cistern (depending on the type between five to twenty litres per flush).

Dual flush toilets are available to reduce water used to flush urine.

Cistern-flush toilets provide the highest level of convenience and have a very clean and hygienic appearance.

The cistern-flush toilet itself has no treatment effects.

Cistern-flush toilets use large amounts of water. Installing them results in a water use of around one hundred litres per person per day.

Because of the complexity of the flush mechanism, cistern-flush toilets are more prone to malfunctioning than pour-flush toilets.

Current Extent of Use:

- extensively throughout the region.

Operation and Maintenance:

- subject to malfunction of flushing system.

Advantages:

- easy to use and clean
- hygienic

Disadvantages /constraints:

- high cost
- high maintenance
- high water use

Relative Cost:

- high

Cultural Acceptability:

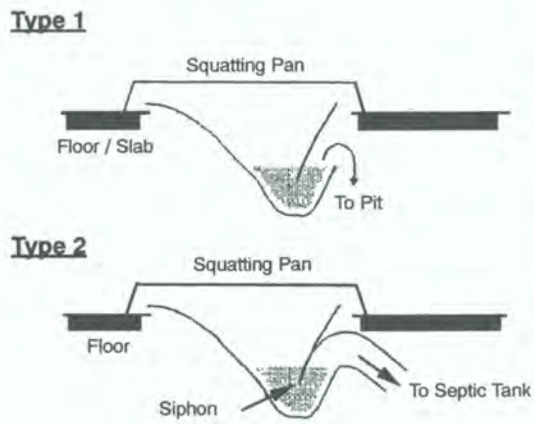
- No cultural problems

Suitability

- Very suitable if reliable water supply exists and if it can be afforded by user.

Collection and Transfer Systems:

Pour-Flush Toilet



Note: The pour flush toilet can also be constructed with a riser to sit on instead of the squat type as shown above.

Source: T. Loetscher (1998)

Technology Description:

The toilet pan consists of a siphon, which provides a water seal against bad odours from the effluent pipe. Excreta are flushed away with water, which is poured manually into the pan by using a scoop. The amount of water required to flush this type of toilet is between two and three litres.

Pour-flush toilets provide a high level of convenience and have a very clean and hygienic appearance.

The pour-flush toilet itself has no treatment effects.

The pour flush toilet can also be constructed with a riser to sit on instead of the squat type as shown.

Current Extent of Use:

- Used moderately throughout the region

Operation and Maintenance:

- Easy to operate and maintain

Advantages:

- Easy to use and clean
- Hygienic
- Uses less ater then cistern-flush toilets

Disadvantages /constraints:

- May become blocked

Relative Cost:

- low

Cultural Acceptability:

- No cultural problems

Suitability

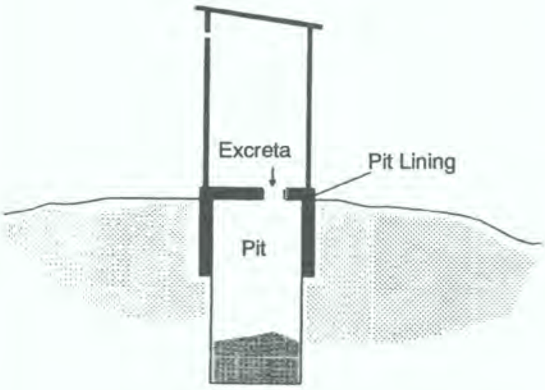
- Very suitable in rural areas with limited water resources
- Where a reliable water source exists, however sea water or rainwater may be used.

4.3 Wastewater Treatment (On-site)

On-site wastewater disposal systems provide for the treatment and disposal of domestic waste either by waterborne or non-waterborne means, normally within the boundaries of individual household properties. Disposal is normally by subsurface soakage and assimilation to soil. On-site systems may be environmentally sound when there is adequate area to dispose of waste so that fresh and coastal waters are not polluted. Typical examples of on-site treatment within the Region, are the various types of latrines and septic tanks. Note that much of the following technology information and diagrams were from T. Loetscher's SANEX Sanitation Expert Systems (1998)

On-Site Wastewater Treatment

Pit Latrine



Source: T. Loetscher (1998)

Technology Description:

The pit latrine is designed for the on-site disposal of human excreta. It consists of a concrete squatting plate or riser, which is placed over an earthen pit. Its design life is between 15 - 30 years. If less than 10 years, a double vault composting (DVC) latrine should be considered instead.
The pit diameter is between 1 - 1.5 m. The depth of the pit is at least 2 m, but usually more than 3 m. The top 0.5 m of the pit always require lining. In loose soil, the entire pit should be lined in order to prevent collapse.
One unit can serve one or several households.

If constructed properly, they provide good health benefits.
All types of anal cleansing materials may be used.
Since ventilation of pit latrines is simple, odours and insect nuisance may occur. Excreta can be seen through the hole in the squatting plate.
A pit latrine can be upgraded to a latrine with vault or a pour-flush latrine.

Current Extent of Use:

- extensively used throughout the region

Operation and Maintenance:

- easy to operate and maintain

Advantages:

- low cost
- encourages public involvement
- pit latrines do not need water for flushing and are simple to construct.
- the potential for self help is high.

Disadvantages /constraints:

- this facility can not receive greywater
- since pit latrines involve soil absorption, there is a danger of groundwater contamination
- odours and insect nuisance may occur

Relative Cost:

- low

Cultural Acceptability:

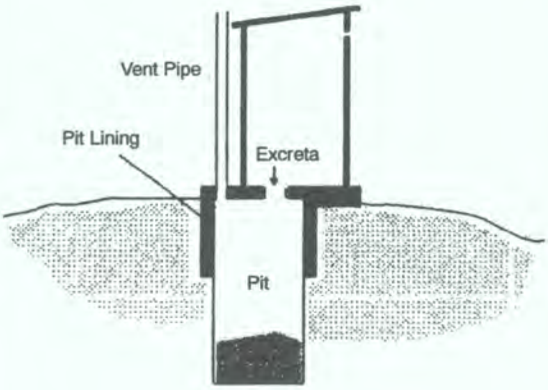
- culturally accepted

Suitability

- Suitable low cost waste disposal method however contamination of groundwater may be an issue

On-Site Wastewater Treatment

VIP Latrine



Source: T. Loetscher (1998)

Technology Description:

The ventilated improved pit (VIP) latrine is designed for the on-site disposal of human excreta. With the exception of some enhancements in design (e.g. a vent pipe) to improve ventilation, its construction is similar to that of the pit latrine.

VIP latrines do not need water for flushing. They rely on soil absorption and are simple to construct. If constructed properly, they provide good health benefits.

All types of anal cleansing materials may be used.

Excreta can be seen through the hole in the squatting plate or riser. A VIP latrine can be upgraded to a latrine with vault or a pour-flush latrine.

Current Extent of Use:

- moderate use in the region

Operation and Maintenance:

- easy to operate and maintain

Advantages:

- one unit can serve one or several households.
- no water required
- the potential for self help is high.
- the ventilation of VIP latrines is good, odours and insect nuisance normally do not occur.

Disadvantages /constraints:

- this facility can not receive greywater.
- there is a danger of groundwater contamination.

Relative Cost:

- high

Cultural Acceptability:

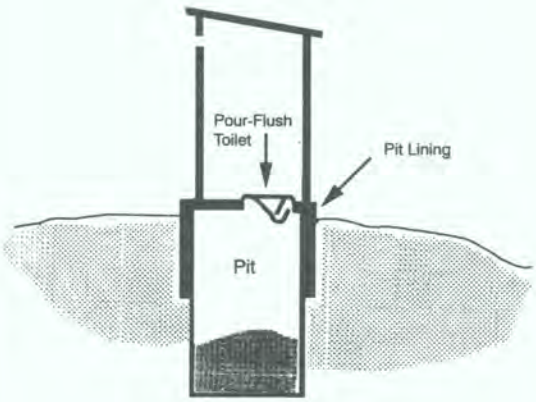
- culturally accepted

Suitability

- Suitable low cost waste disposal method however contamination of groundwater may be an issue

On-Site Wastewater Treatment

Pour-Flush Latrine



Source: T. Loetscher (1998)

Technology Description:

The pour-flush latrine is designed for the on-site disposal of human excreta. Its construction is similar to that of the pit latrine, except that it uses a pour-flush pan instead of a squatting plate with a hole in it.

One unit can serve one or several households.

If constructed properly, they provide good health benefits.

The water seal in the pour-flush pan forms an effective barrier against odours and insect nuisance, and prevent excreta from being seen once flushed

A pour-flush latrine can be upgraded to a pour-flush toilet with vault.

Current Extent of Use:

- commonly used throughout the region

Operation and Maintenance:

- easy to operate and maintain

Advantages:

- pour-flush latrines need small amounts of water for flushing.
- they are simple to construct, thus the potential for self help is high

Disadvantages /constraints:

- this facility cannot receive greywater.
- since pit latrines involves soil absoption, there is a danger of groundwater contamination.

Relative Cost:

- low

Cultural Acceptability:

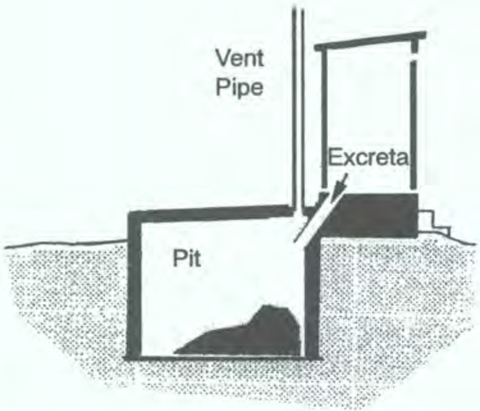
- culturally accepted

Suitability

- Suitable for household use, however contamination of groundwater may be an issue.

On-Site Wastewater Treatment

Reed Odourless Earth Closet



Source: T. Loetscher (1998)

Technology Description:

The Reed odourless earth closet (ROEC) is designed for the on-site disposal of human excreta. From the concrete squatting plate or riser, an inclined chute leads to the completely off-set pit. Ventilation is similar to the VIP latrine. Its design life is between 15 - 30 years. If less than 10 years, a double vault composting (DVC) latrine should be considered instead. Because it is off-set, the pit can be built larger than that of the conventional pit latrine. In loose soil, the entire pit should be lined in order to prevent collapse.

ROECs do not need water for flushing and are simple to construct. If constructed properly, they provide good health benefits.

All types of anal cleansing materials may be used. Since the chute is inclined, excreta cannot be seen through the hole in the squatting plate.

Since ROECs involve soil absorption, there is a danger of groundwater contamination. A ROEC can be upgraded to a latrine with vault or a pour-flush latrine.

Current Extent of Use:

- Limited use

Operation and Maintenance:

- easy to operate and maintain
- chute must be kept clear of blockages

Advantages:

- one unit can serve one or several households.
- Does not require water
- the potential for self help is high.
- Good ventilation largely prevents odours and insect nuisance.

Disadvantages /constraints:

- this facility can not receive greywater.
- fouling of the chute is often a problem
- danger of groundwater contamination

Relative Cost:

- moderate

Cultural Acceptability:

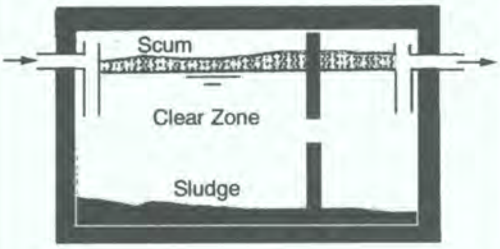
- culturally accepted

Suitability

- Suitable for household use, however contamination of groundwater may be an issue.

On-Site Wastewater Treatment

Septic Tank



Note: Effluent from the septic tank should be disposed of through drainage fields, see page pits or sewerage system

Source: T. Loetscher (1998)

The effluent of septic tanks is still heavily contaminated with pathogens. Therefore, its disposal requires either soil absorption facilities or sewerage. An exception to this are septic tanks for excreta reuse.

Septic tanks that discharge into a soil absorption system can be upgraded to settled sewerage.

Technology Description:

The septic tank is designed for the on-site treatment of domestic sewage. The tank is located underground and usually consists of two compartments. The first compartment is approximately twice as large as the second one. Septic tanks can be constructed with only one compartment. However, this will result in significantly reduced treatment effects and cost savings are minimal.

There are two main treatment effects:

1) Contaminants are removed from the sewage by either settling of heavy particles or by flotation of materials less dense than water (e.g. oils and fats). The sludge layer at the bottom of the tank is a result of the settling process. The scum layer is formed through the flotation process.

2) Subsequently, organic matter in the sludge as well as the scum layer is digested by bacteria. As a result, gas is produced which emerges through a ventilation opening in the tank. The digestion process is important because it prevents the excessive accumulation of sludge.

Septic tanks can reduce the BOD of raw sewage by up to 40% and the suspended solids content by 65%. Their effluent is thus much more readily absorbed into the ground than raw sewage. Therefore, smaller soil absorption facilities (e.g. seepage pit or drain field) are required.

Effluent quality can be further improved by installing a solids filter on the septic tank outlet.

This prevents the carry over of solids into the absorption field.

Since they can only accept liquid waste, they must be connected to a flush toilet. Thus they are not suitable where water supply is scarce or unreliable.

Current Extent of Use:

- extensively used in all countries of the region

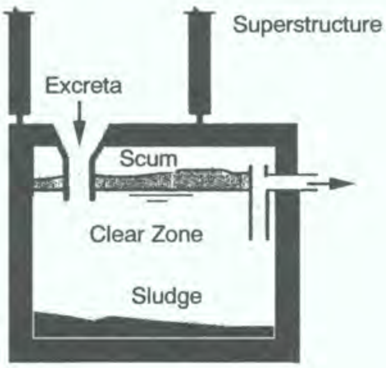
Operation and Maintenance:

- depending on their design, septic tanks require routine checks for sludge and scum levels and desludging every one to three years.

Advantages:	Disadvantages /constraints:
• greywater can be treated together with toilet waste. • there is some potential for self help.	• the construction of septic tanks requires skilled labour • if this maintenance is neglected, septic tanks produce very poor effluent and can become a serious environmental and health hazard.
Relative Cost: • high	**Cultural Acceptability** • culturally accepted
Suitability • very suitable if designed, constructed and maintained properly and used with trench drainage system.	

On-Site Wastewater Treatment

Aquaprivy



Note: Effluent should be disposed of through drainage field or see page pit

Source: T. Loetscher (1998)

Technology Description:

The aquaprivy is designed for the on-site collection and treatment of domestic sewage. Excreta fall through a submerged chute into a watertight tank, which is located underground. The liquid in the tank provides a water seal to reduce odours and insect nuisance.

There are two main treatment effects:

1) Contaminants are removed from the sewage by either the settling of heavy particles or by flotation of materials less dense than water (e.g. oils and fats). The sludge layer at the bottom of the tank is a result of the settling process. The scum layer is formed through the flotation process.

2) Subsequently, organic matter in the sludge as well as the scum layer is digested by bacteria. As a result, gas is produced which emerges through a ventilation opening in the tank. The digestion process is important because it prevents the excessive accumulation of sludge.

Greywater has to be collected and discharged separately.

Current Extent of Use:

- Limited use

Operation and Maintenance:

- accumulated sludge needs to be pumped out every one to three years, which requires special equipment such as vacuum trucks.
- for flushing and in order to maintain the water seal, approximately five litres of water is required per person per day.
- besides cleaning the chute, there is no other maintenance required.

Advantages:

- there is some potential for self help
- aquaprivies can be upgraded to septic tanks and settled sewerage.

Disadvantages /constraints

- if not well constructed, tanks are not watertight. As a consequence, it is difficult to maintain the liquid level and thus the water seal, with resulting bad odours, and the risk of groundwater contamination

Relative Cost:

- high

Cultural Acceptability:

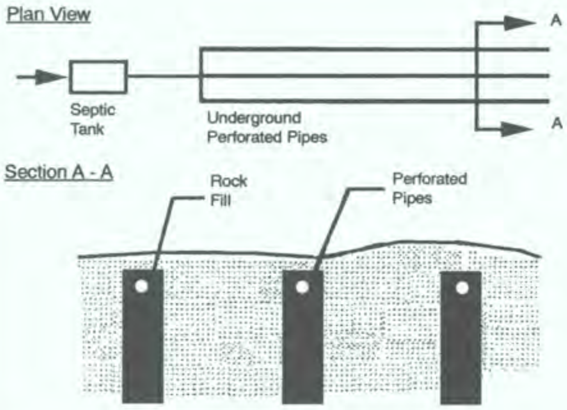
- culturally accepted

Suitability

- may be suitable if space is a problem, otherwise septic tanks are a better option.

On-Site Wastewater Treatment

Drain Field



Source: T. Loetscher (1998)

Technology Description:

The drain field is designed for the on-site disposal of sewage. It is an area of land consisting of one or several long trenches, into which sewage is discharged through underground perforated pipes. The sewage percolates into the ground while it is decomposed by bacteria in the soil.

Usually, one drain field receives the effluent from one septic tank or aquaprivy.

If sized large enough, a drain field can also accept greywater.

The size and the cost of drain fields depend on the absorption capacity of the soil.

The life of a drainage field can be extended by placing a solids filter on the outlet of the septic tank to prevent solids entering and blinding the drainage field.

Current Extent of Use:

- limited usage because seepage pits are easier and cheaper to construct

Operation and Maintenance:

- if constructed properly, no maintenance is required
- but if clogged, replacement trenches are required sooner
- O & M reduced if septic tank or other system using trenches are maintained properly

Advantages:

- the construction of drain fields is simple with good potential for self help
- better disposal method than seepage pits

Disadvantages /constraints

- large space requirements.
- since drain fields are based on soil absorption, there is a danger of ground water contamination

Relative Cost:

- high

Cultural Acceptability:

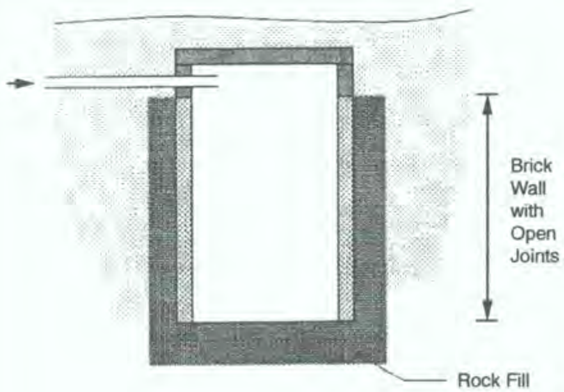
- culturally accepted

Suitability

- very suitable to dispose of septic tank effluent where enough space is available, and where the soil has medium absorption capacity (not too slow, and not too fast resulting in ground water contamination)

On-Site Wastewater Treatment

Seepage Pit



Note: In the region often seepage pits consist of a dug pit back filled with rocks or coral blocks

Source: T. Loetscher (1998)

Technology Description:

The seepage pit is designed for the on-site disposal of sewage effluent. It consists of an underground pit, the wall of which is lined with bricks. Through the open joints in the brick lining, effluent percolates into the soil, where it is decomposed by microorganisms.

Usually, one seepage pit receives the effluent from one septic tank or aquaprivy.

If sized large enough, a seepage pit can also accept greywater.

The size and thus the cost of a seepage pit depends on the absorption capacity of the soil.

Current Extent of Use:

- seepage (or soakage) pits are extensively used in the region - however often not built to the standard shown here.

Operation and Maintenance:

- if constructed properly, minimal maintenance is required
- O & M reduced if septic tank or other system using trenches are maintained properly

Advantages:

- the construction of a seepage pit is simple with good potential for self help.

Disadvantages /constraints

- seepage pits are based on soil absorption, there is a danger of groundwater contamination more so then with drainage trenches, as effluent is concentrated at one point rather than spread over a large area

Relative Cost:

- moderate

Cultural Acceptability:

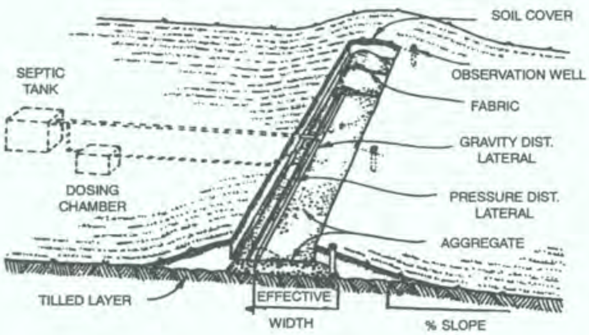
- culturally accepted

Suitability

- to dispose of septic tank effluent where potential groundwater contamination is not an issue.

On-Site Wastewater Treatment

Wisconsin Mound (raised bed)



Source: Tyler & Peterson

Note: The life of a Wisconsin mound can be extended by placing a solids filter on the outlet of the septic tank to prevent solids entering and blinding the mound.

Technology Description:

Wisconsin mounds are used for those soil and site conditions where conventional disposal trenches are unsuited due to shallow soils overlaying rock, or where water tables are high in permeable soils. The mound provides for distribution of effluent onto a layer of sand of sufficient depth (around 600mm) to ensure satisfactory renovation before entering the natural soil to then diffuse into the watertable. The mound is constructed directly onto the natural ground surface, which is ploughed or cultivated beforehand. Wastewater renovation takes place within the sand fill of the mound, enabling the unit to be placed on freely permeable or slowly permeable subsoils. It can even be utilised on filled areas. Wastewater renovation takes place within the sand fill of the mound, enabling the unit to be placed on freely permeable or slowly permeable subsoils.

If sized large enough, a Wisconsin mound can also accept greywater.

The size and the cost of Wisconsin mounds depend on the absorption capacity of the soil.

Current Extent of Use:

- low usage because seepage pits are easier and cheaper to construct

Operation and Maintenance:

- if constructed properly, minimum maintenance is required
- O & M reduced if septic tank or other system using trenches are maintained properly

Advantages:

- the construction of a seepage pit is simple with good potential for self help.

Disadvantages /constraints

- large space requirements.
- since Wisconsin mounds are based on soil absorption, there is a danger of ground water contamination
- higher cost than a drain field

Relative Cost:

- medium - high

Cultural Acceptability:

- culturally accepted

Suitability

- very suitable to dispose of septic tank effluent where enough space is available, and where the soil has medium absorption capacity (not too slow, and not too fast resulting in ground water contamination)

4.4 Wastewater Treatment (Centralised and Decentralised)

Generally the major difference between centralised and decentralised treatment system technologies is the population that they are designed to service, with centralised systems servicing larger urban areas. All of these treatment systems require the use of water throughout the process to flush, convey, treat and dispose of waste and wastewater. Wastewater treatment processes are classified into the following categories, related generally to the quality of effluent produced by the process.

4.4.1 Preliminary Treatment

The aim of preliminary treatment is to protect the principal treatment processes that follow by the removal of solids and grit which can block and wear pipe work, valves, pumps and treatment equipment. Modern preliminary treatment consists of screening, grit and grease removal and to a lesser extent, shredding devices. In Mauritius preliminary treatment is the only form of treatment before being discharged in to the sea.

4.4.2 Primary Treatment

Sedimentation is generally the main operation in the Primary treatment process. Sedimentation can remove all the readily settleable matter from the wastewater, giving a corresponding reduction in Suspended Solids (SS) and Biochemical Oxygen Demand (BOD) concentrations. Grease and fatty materials float to the surface to form a scum which can be removed. This standard of treatment may be considered satisfactory for ocean disposal of effluent, assuming that the outfall is properly designed and constructed.

A number of different types of sedimentation tanks or clarifiers are used for primary sedimentation including septic tanks, Imhoff tanks, clarigestors, rectangular, and circular tanks.

4.4.3 Secondary Treatment

Secondary treatment basically consists of some form of biological process. The main objective of secondary treatment is to remove most of the fine suspended and dissolved degradable organic matter which remains after primary treatment, so that the effluent may be rendered suitable for discharge. This is normally achieved by aerobic biological processes. The processes most widely used in municipal treatment systems are trickling filters, rotating biological filters, activated sludge and oxidation ponds. Aerated lagoons are also used for municipal treatment and for pre-treating industrial effluents.

4.4.4 Tertiary Treatment

Tertiary treatment is carried out where the effluent must be of a higher quality than that obtainable by secondary treatment. The main objective is usually effluent polishing (the removal of fine suspended solids). Because these are mostly organic, their removal will result in a reduction in the effluent BOD. Effluent polishing can be carried out using physical separation of suspended solids from the effluent or by more complex processes which involve biological as well as physical action. Physical separation processes include microstrainers and various types of filter ranging from slow sand filters to rapid sand, dual media and mixed media filters. Processes involving biological action include tertiary ponds, grass filtration, land filtration and wetlands.

Other processes, which are gaining greater use in tertiary treatment, include ozonation and UV radiation, which act to reduce levels of pathogens in the effluent.

Most "package" plants available provide secondary treatment. However when used in conjunctions with another secondary treatment process may provide tertiary treatment.

Most of the following technology information is from SOPAC's *Report on Project Criteria, Guidelines and Technologies* (1999) by H Scholzel and R Bower.

Municipal, predominantly domestic wastes, represent the most common type of effluent, and for this reason their treatment is fairly well standardized and are of particular importance in water pollution management. Table 1 provides some qualitative information about the expected performance efficiencies of certain commonly used primary, secondary and tertiary treatment processes. Some general specifications for processes employed in wastewater treatment are given in Table 2. Furthermore, Tables 3 and 4 provide qualitative guidance regarding the relevant cost and performance reliability of secondary (biological) treatment systems.

Table X: TYPICAL PERFORMANCE EFFICIENCIES FOR MUNICIPAL WASTEWATER TREATMENT PROCESSES (WHO (1993) Assessment of Sources of Air, Water and Land Pollution, Part Two)

Treatment Process	BOD Removal %	TSS Removal %	Nitrogen Removal %	Phosphorus Removal %	Bacteria Removal %	Viruses Removal % Log_{10} units
Primary Treatment						
Screening	5 - 10	2 - 20			10 - 20	
Grit Chambers	10 - 20	20 - 40			10 - 20	
Skimming	20 - 30	20 - 40			10 - 20	
Sedimentation	30 - 35	60 - 65	7.5	10	25 - 75	0 - 1
Secondary Treatment						0 - 1
ChemicalCoagulation	50 - 85	70 - 90	25	85	40 - 80	0 - 1
High Rate Trickling Filter	65 - 95	65 - 92			80 - 95	0 - 1
Low Rate Trickling Filter	90 - 95	70 - 92			90 - 95	0 - 1
Activated Sludge	85 - 93	85 - 90	30 - 40	30 - 45	60 - 90	0 - 1
Extended Aeration	95 - 98	85 - 90	15 - 30	10 - 20	60 - 90	0 - 1
Aerated Lagoon	70 - 90				60 - 96	1 - 3
Waste Stabilization Ponds	70 - 90		40 - 50	20 - 60	60 - 99 9+	1 - 4
Tertiary Treatment						
Disinfection					99 - 99 9+	0 - 4

Table XI: SOME GENERAL SPECIFICATIONS FOR PROCESSES EMPLOYED IN WASTEWATER TREATMENT (WHO (1993) Assessment of Sources of Air, Water and Land Pollution. Part Two)

Process	Performance	Sizing
Simple Sedimentation (Primary treatment)	60% removal of suspended solids 35% removal of BOD	2 - 3 hours detention of wastewater 3 - 4 meter deep tank Some sludge removal mechanism
Facultative pond or lagoon (part aerobic and part anaerobic) (primary treatment probably not required)	Effluent is : ≤ 30 mg/l SS ≤ 30 mg/l BOD	1 - 2 deep Area required is 37^2 land/area/m^3/day of flow for 11 - 110 kg/ha/day BOD removal. Usually used for cities of <10,000 people in size
Trickling filter (Will generally include a primary and secondary clarifier)	85% removal of suspended solids and BOD Effluent is : Approx. 30mg/l BOD and Approx. 30mg/l SS	No air addition required 1 - 3 meter deep rock bed. Rocks are 3 - 12 cm in diameter. Primary effluent is distributed over bed. Loading $1m^2$ area/m^3 day of flow volume with rock media. Can do better with red wood or plastic media. Occupy about 80 - 320 g/m^3 capacity.
Activated sludge Air introduced into sewage suspension followed by sedimentation - generally sewage / wastewater has first been clarified)	Effluent is : ≤ 30 mg/l SS ≤ 30 mg/l BOD and / or 90% BOD removal	Retention time is 4-8 hours Tank depth of 3 - 6 m Width < 9m Organic loading 1.6 - 3.2 kg BOD/d/m^3 Diffused Air 56 - 69 m^3 kg of BOD
Note : Special case of extended aeration process (24 hour aeration)		
Land treatment Slow Rate (irrigation)	< 2 BOD < 1 SS O FC/100 ml	Apply 1 6 m/yr Need 540 - 7000 m^2area/area/m^3day of flow As min. precede w/primary
Rapid Infiltration	5 mg/l BOD 2 mg/l SS 10 FC/100ml	Apply 6 - 125 m/yr Need 64 - 750 m^2 area/m^3day of flow As min precede w/primary

Table XII : COMPARISON OF COST PARAMETERS FOR BIOLOGICAL TREATMENT PROCESSES (WHO (1993) Assessment of Sources of Air, Water and Land Pollution. Part Two)

Land Requirements :			
	Waste Stabilization Ponds		
High		Area, m^2/capita	: 2 - 4 (warm) 4 - 12 (temperate
	Facultative Aerated lagoons		
		Area, m^2/capita	: 0.15 - 0.45 (warm) & 0.45 - 1.00 (temperate)
	Extended Aeration Systems		
		Area, m^2/capita	: 0.25 - 0.35 (warm) & 0.35 - 0.65 (temperate)
	Conventional Activated Sludge		
		Area, m^2/capita	: 0.16 - 0.20 (warm) & 0.20 - 0.40 (temperate)
Low	Trickling Filters		
		Area, m^2/capita	: 0.16 - 0.20 (warm) & 0.20 - 0.40 (temperate)
Cost of Construction (Excluding Land Cost)			
	Extended Aeration Systems		
High		Equipment	: Aerators, recycle pumps, sludge scrapers
		Economy of scale	: Considerable
	Conventional Activated Sludge		
		Equipment	: Aerators, recycle pumps, scrapers, thickeners, digesters, driers
		Economy of scale	: Small
	Trickling Filters		
		Equipment	: Effluent distributors
		Economy of scale	: Small
	Facultative Aerated lagoons		
		Equipment	: Aerators only
		Economy of scale	: Very small
Low	Waste Stabilization Ponds		
		Equipment	: Nil
		Economy of scale*	: Very small
Operating Cost :			
High	Conventional Activated Sludge		
		Operation	: Skilled operators / Light control
		Sludge Handling	: Drying beds or Mechanical dewatering
		Power Requirements	: 12 - 17 kWh/person/year
	Extended Aeration Systems		
		Operation	: Skilled operators
		Sludge Handling	: Digest + Drying beds / filters
		Power Requirements	: 13 - 20 kWh/person/year
	Trickling Filters		
		Operation	: Relatively simple
		Sludge Handling	: Digest + Drying beds / filters
		Power Requirements	: Low
	Facultative Aerated lagoons		
		Operation	: Very simple
		Sludge Handling	: Manual desludging every 5 - 10 years
		Power Requirements	: 12 - 15 kWh/person/year
	Waste Stabilization Ponds		
		Operation	: Simplest (Part time operator for small units)
Low		Sludge Handling	: Manual desludging every 5 - 10 years
		Power Requirements	: 0 kWh/person/year

* Sensitivity of Unit Cost (construction cost per capita) to the size of Population Served

Table XIII : COMPARISON OF THE OPERATING RELIABILITY OF BIOLOGICAL TREATMENT PROCESSES (WHO (1993) Assessment of Sources of Air, Water and Land Pollution. Part Two)

Adaptation to Organic and Toxic Shock Loads :

High	Waste Stabilization Ponds
↓	Facultative Aerated Lagoons
	Trickling Filters
	Extended Aeration Systems
Low	Conventional Activated Sludge

Suitability for Intermittent Operation :

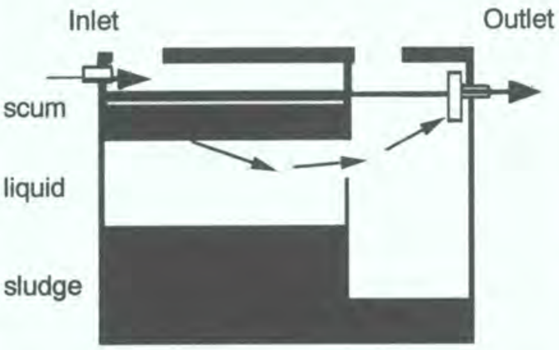
High	Waste Stabilization Ponds
↓	Facultative Aerated Lagoons
	Trickling Filters, Biodiscs
	Extended Aeration Systems
Low	Conventional Activated Sludge

Independence from Operators' Training :

High	Waste Stabilization Ponds
↓	Facultative Aerated Lagoons
	Trickling Filters, Biodiscs
	Extended Aeration Systems
Low	Conventional Activated Sludge

Primary Process

Septic Tank



Source: Flow Principle of the septic tank after Ludwig, S. 1998.

Technology Description:

Septic tanks are mainly designed for on-site treatment of domestic sewage and are small, rectangular chambers situated just below ground level where sewage is retained for 1-3 days. They usually consist of 2 compartments with the first larger then the second. Solids settle to the bottom of the tank where they are digested anaerobically. A thick crust of scum is formed at the surface and helps maintain anaerobic conditions. Some sludge accumulates at the bottom of the tank that needs regular desludging. Biogas is produced in a septic tank as sludge decomposes and gas rises to the surface as bubbles. The gas then accumulates on the surface above the liquid from where it should allowed to escape into the air. Septic tank effluent is then left to drain away in soakaways.

This is rough primary treatment prior to secondary or tertiary treatment, the effluent quality achievable is:

- 25-50% COD removal
- 40% BOD reduction of raw sewage
- 65% Suspended Solids reduction
- effluent still contains pathogenic bacteria, cysts and worm eggs.

Both greywater and blackwater can be flushed through the system. Since it only accepts liquid waste it must be connected to a flush toilet.

Current Extent of Use:

- Used throughout the region

Operation and Maintenance:

- Little maintenance however requires regular desludging

Advantages:

- Low land space required
- No electrical requirements
- Low operational and maintenance requirements
- Construction material locally available

Disadvantages / constraints:

- Low effluent quality.
- Still heavily contaminated with pathogens, cysts and worm eggs.
- Construction of septic tank requires skilled labour

Relative Cost:

- Low

Cultural Acceptability:

- Is generally accepted within the region

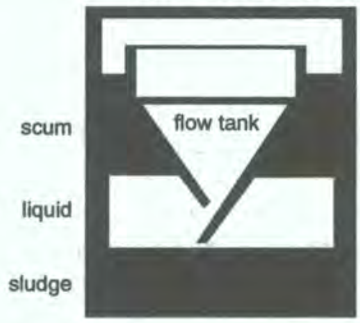
Suitability:

- Not where water supply is scarce or unreliable

Primary Process

Imhoff Tanks

Cross Section



Source: Flow Principle of the Imhoff Tank after Ludwig, S. 1998

Technology Description:

Imhoff tanks are used for domestic or mixed wastewater flows where effluent will undergo further treatment on ground surface.

The Imhoff tank is divided into an upper settling compartment in which sedimentation of solids occurs. Sludge then falls through opening at the bottom into the lower tank where it is digested anaerobically. Methane gas is produced in the process and is prevented from disturbing the settling process by being deflected by baffles into the gas vent channels. Effluent is odourless because the suspended and dissolved solids in the effluent do not come into contact with the active sludge causing it to become foul. When sludge is removed needs to be further treated in drying beds or such for pathogen control.

The treatment efficiency is equivalent to primary treatment. It can achieve 40% BOD reduction, 65% Suspended solids reduction. But it has a poor pathogen removal

Since they only accept liquid waste the tanks must be connected to a flush toilet. Both greywater and blackwater can be flushed through the system

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

- Require removal of scum and sludge at regular intervals.
- Apart from desludging and removal of scum no significant maintenance required.

Advantages:

- Low land space required
- No electrical requirements
- Low operational and maintenance requirements
- Construction material locally available

Disadvantages / constraints:

- Effluent still contaminated with pathogens.
- Construction of Imhoff tanks requires skilled labor
- Needs skilled contractors for construction
- Poor effluent quality

Relative Cost:

- Low

Cultural Acceptability:

- Is generally accepted within the region

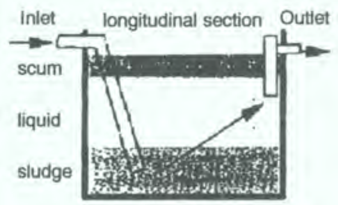
Suitability:

- Not suitable where water supply scarce or unreliable.

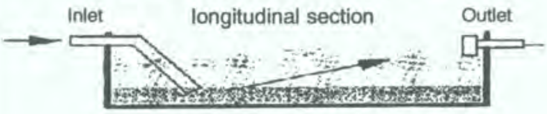
Primary Process

Ponds/Tanks

High Loaded Anaerobic Pond



Low Loaded Anaerobic Pond



Source: Principle of anaerobic ponds after Ludwig, S. 1998

Technology Description:

Anaerobic ponds use the same biological process and same basis for loading as septic tanks but on a much larger scale. Anaerobic Ponds as the name implies operates in the absence of air. Therefore deep tanks with small surface areas operate more efficiently then shallower ponds. Before use ponds should be filled with water to prevent foul conditions from occurring. After the addition of raw sewage sludge will accumulate on the bottom of the pond and in a week or so a crust will form on the surface which eliminates all odours. The wastewater type and the method of post treatment outlines the role of the anaerobic ponds. Anaerobic ponds are designed for hydraulic retention times of between 1-30 days depending on strength and type of wastewater and also the desired treatment effect. Stormwater could cause shock volumetric loads which may affect the performance of ponds and should be taken into account in earlier stages of pond development.

The effluent quality that can be achieved are as follows:

- small ponds treating domestic wastewater 50-70% BOD removal,
- high loaded ponds with long Hydraulic Retention Times, 70-95% BOD removal, 65-90% COD removal
- Treatment Efficiency of low loaded ponds with short Hydraulic Retention Time of 72 hours, 57% BOD removal, 53% COD removal
- Treatment efficiency of low loaded ponds with long Hydraulic Retention Time of 480 hours, 98% BOD removal, 96% COD removal

Both greywater and blackwater can be flushed through the system

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

- Apart from being filled with water before use the start up to these ponds require no significant arrangements.
- Sludge gradually accumulates in ponds and requires removal at regular intervals.

Advantages:

- No electrical requirements
- Low operational and maintenance requirements
- Construction material locally available
- High effluent quality for low loaded ponds with long HRT

Disadvantages / constraints:

- Poor effluent quality for low loaded ponds with short HRT or domestic water.
- Low effluent quality for small ponds treating dometic wastewater

Relative Cost:

- Moderate Costs

Cultural Acceptability:

- Is generally accepted within the region

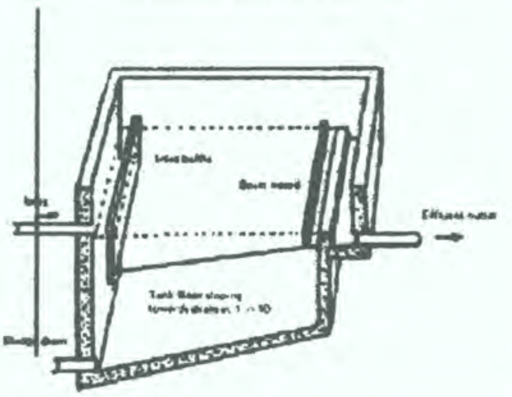
Suitability:

- Moderate land requirements for both ponds with short HRT and long HRT as in comparison with other technologies presented in this report however ponds with long HRT require significantly more land than short HRT ponds.

Primary Process

Ponds/Tanks

Sedimention Tanks



Source: Horizontal Flow Type after Mann, H.T., Williamson, D., 1982

Technology Description:

Raw sewage contains a lot of insoluble suspended matter which can be settled in properly designed sedimentation tanks of which there are two types upward flow and horizontal flow. The tank has a sloping floor to assist sludge removal that is done by gravity through a valve at the lowest point of the tank. The main action that occurs here is the settling of the insoluble suspended particles and a properly designed sedimentation tank can remove about half of this polluting matter. Effluent leaving here can be further treated in stabilization ponds, percolating filters etc.

The effluent quality that can be achieved is as follows:

- Low loaded tanks with short Hydraulic Retention Times 57% BOD removal, 53% COD removal
- Low loaded tanks with long Hydraulic Retention Times 98% BOD removal, 96% COD removal

Both greywater and blackwater can be flushed through the system. Since they only accept liquid waste they must be connected to a flush toilet.

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

- Sludge removal is important and must be done regularly
- Other then desludging no significant maintence required

Advantages:

- No electrical requirements
- Low operational and maintenance requirements
- Construction material locally available
- High effluent quality for low loaded tanks with long HRT

Disadvantages / constraints:

- Low effluent quality for low loaded tanks with short HRT

Relative Cost:

- Low

Cultural Acceptability:

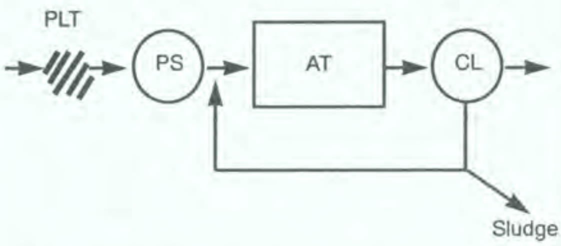
- Is generally accepted within the region

Suitability:

- Not suitable where water supply scarce or unreliable as requires high volumes of water for transportation to treatment site.
- Moderate land requirements for both ponds with short HRT and long HRT as in comparison with some technologies presented in this report however ponds with long HRT require significantly more land than short HRT ponds.

Secondary Process

Activated Sludge Treatment



PLT = Preliminary Treatment
PS = Primary Settling
At = Aeration Tank
CL = Clarifier

Source: After Loetscher T., 1998

Technology Description:

Activated sludge treatment is a train of processes designed to treat wastewater collected from a sewer network. The preliminary treatment removes coarse solids and grease and primary settling allows further removal of solids. It is in the Aeration tank that micro-organisms use oxygen to breakdown organic pollutants. Flocs are formed which settle in clarifier forming a sludge layer that is then disposed in drying beds etc. at a sludge disposal site. The clear liquid left in the clarifier can either be further treated or discharged. Suitable for blackwater as well as greywater.

The treatment efficiency achievable is 95% BOD removal and 90% Suspended Solids removal

Since they only accept liquid waste must be connected to a flush toilet.

Current Extent of Use:

- Moderately used in the region. Used specially for hotels effluent treatment

Operation and Maintenance:

- Implementation requires skilled labour and contractors
- Require expert staff for operation and maintenance
- Process needs constant monitoring and control

Advantages:

- Low land requirements
- High Effluent quality

Disadvantages / constraints:

- Needs skilled contractor for construction
- Importation of some construction material
- Needs trained operator
- Requires electricity
- High operation and maintenance

Relative Cost:

- High cost

Cultural Acceptability:

- Is generally accepted within the region

Suitability:

- Not suitable where water supply scarce or unreliable as requires high volumes of water for transportation to treatment site.

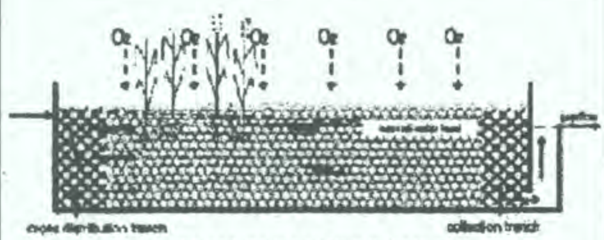
Secondary Process

Wetlands/Ponds

Reed Bed System/ (SSF) Subsurface Flow/Wetlands/Root Zone Treatment Plants/Horizontal Gravel Filter

Principle of horinzontal filter process

continuous oxygen supply to the upper layers only
major role of plants: provide favourable environment for bacteria diversity



anaerobic and anoxic conditions in the lower layers

Source: Principle of the Horizontal Filter after Ludwig, S. 1998

Technology Description:

Wetlands systems are suitable for domestic and industrial wastewater that has undergone preliminary treatment and that has a COD content not higher than 500mg/l. The reed bed system is 1m deep basin sealed with clay or some other form of lining to prevent percolation into groundwater with the basin itself being filled with soil in which reeds are then planted. Oxygen is transported through the pores of the plant down to the roots whereby the oxygen content increases the biological activity of the soil. When wastewater runs through the root zone soil organic compounds and other impurities are eliminated by micro-organisms in the soil.

The effluent quality achieved is up to 84% COD removal rate and up to 86% BOD removal rate

Current Extent of Use:

- Not currently used in the region but has a potential for being implemented.

Operation and Maintenance:

- Generally low operation and maintenance required, however does need maintaining of reeds or wetland plants to keep weeds out and keep good growth.
- Regular maintenance of erosion trenches

Advantages:

- Low operation and maintenance
- No electrical requirement
- Construction material locally available.
- High effluent quality

Disadvantages / constraints:

- Large area
- Insect breeding

Relative Cost:

- Moderate

Cultural Acceptability:

- Should be accepted within the region

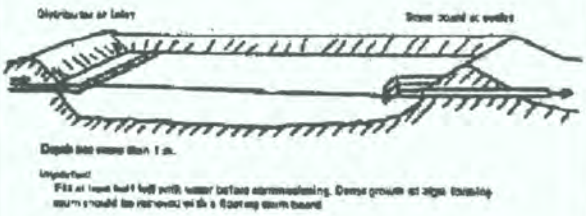
Suitability:

- Since only receive liquid waste not suitable where water scarce or unreliable.
- Requires high volumes of water for transportation to treatment site

Secondary Process

Ponds

Aerobic Stabilisation Ponds / Algal Ponds / Oxidation Ponds



Source: After Mann, H.T., Williamsom, D., 1982

Technology Description:

In aerobic stabilization ponds the organic matter causing pollution is consumed by biological organisms that need oxygen in proportion to the amount of organic matter removed. Oxygen is supplied in these ponds by a growth of algae, which is dependent on photosynthesis. If there is not enough oxygen supplied to organisms that consume organic matter then they will not function and anaerobic organisms will become active causing offensive odours and polluted effluent to be produced. Aerobic ponds should be half-filled with water before use to prevent offensive conditions from occurring. The treatment efficiency increases with longer retention times.

Typical effluent quality is 82% BOD removal rates, up to 97% BOD removal in multiple pond systems, 78% COD removal and 95% pathogen removal.

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

- Regular desludging in defined intervals and start up needs special arrangement.

Advantages:

- Low operation and maintenance required
- No electrical requirement
- Construction material locally available.
- High effluent quality

Disadvantages / constraints:

- Large area
- Insect breeding

Relative Cost:

- Moderate

Cultural Acceptability:

- Is generally not well accepted in the region because of land requirement

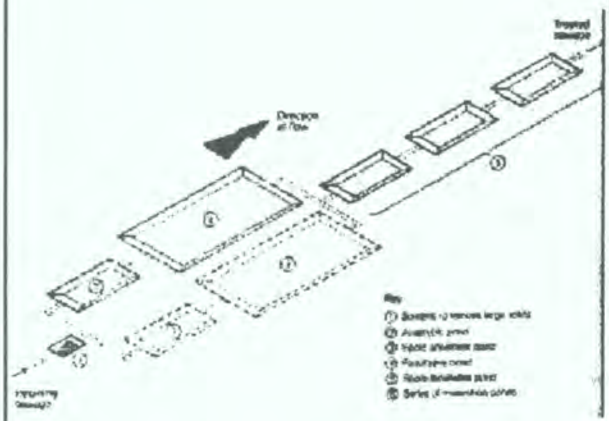
Suitability:

- Since only receive liquid waste not suitable where water scarce or unreliable.
- Requires high volumes of water for transportation to treatment site
- Moderate land requirement, although if aeration provide land required even less

Secondary Process

Ponds

Waste Stabilization Ponds



Source: After Pickford, J., 1991

Technology Description:

Waste stabilization ponds are 3 or more, large, shallow, man-made lakes or ponds in a sequence designed to treat wastewater collected from either a sewer network or from small bore sewers etc. Simply sewage which has been screened to remove large solids enters a system of ponds the first being the anaerobic pond which receives the raw sewage. Some wastes float to the surface as scum which then prevents the pond from being aerated by wind and turning aerobic. Other wastes sink to the bottom as sludge where they are digested by anaerobic bacteria. Effluent then enters the facultative pond that has an aerobic zone close to pond surface and a deeper anaerobic zone. Pathogen removal occurs in the last maturation pond, which is an aerobic pond whereby oxygen is transferred to water by wind and algae. Warm temperatures accelerate the treatment of wastes.

Typical effluent quality is 95% BOD removal and 90% Suspended Solids removal. They produce very clear effluent equivalent to activated sludge treatment.

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

- Grass around ponds need to cut regularly
- Regular desludging is required

Advantages:

- Low operation and maintenance required
- No electrical requirement
- Construction material locally available.
- High effluent quality

Disadvantages / constraints:

- Large area
- Insect breeding

Relative Cost:

- Moderate

Cultural Acceptability:

- Is generally not well accepted within the region

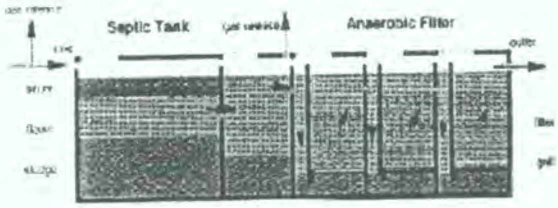
Suitability:

- Since only receive liquid waste not suitable where water scarce or unreliable.
- Requires high volumes of water for transportation to treatment site

Secondary Process

Filters

Anaerobic Filters/Fixed Bed Reactor/Fixed Film Reactor



Source: Flow principle of anaerobic upflow filter after Ludwig, S. 1998

Technology Description:

The anaerobic filter is suitable for domestic wastewater and all industrial wastewater that have a lower content of suspended solids. Anaerobic filters allow the treatment of non-settleable and dissolved solids by bringing them into close contact with surplus active bacterial mass. The dispersed or dissolved organic matter is digested by bacteria within short retention times. Bacteria fix themselves to filter material like gravel, rocks, cinder etc. allowing incoming wastewater to come into contact with active bacteria. Preliminary treatment may be required to remove solids of larger size.

Typical effluent quality is moderate with a 70-90% BOD removal in a well operated anaerobic filter.

Both greywater and blackwater can be flushed through the system.

Current Extent of Use:

- Not currently use in the region

Operation and Maintenance:

- High operation and maintenance
- Desludging required at regular intervals
- Cleaning of filter material required

Advantages:

- Low land requirement

Disadvantages / constraints:

- High operation and maintenance requirements
- Requires electricity

Relative Cost:

- High Cost

Cultural Acceptability:

- Should be accepted within the region

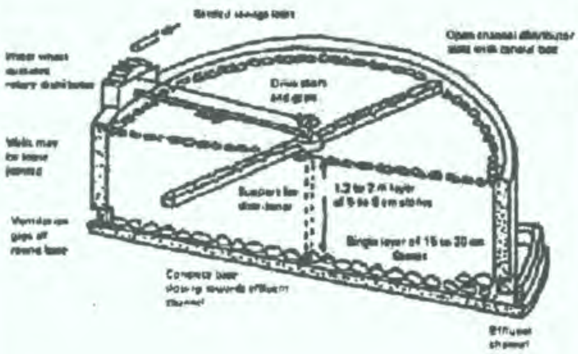
Suitability:

- Since only receive liquid waste not suitable where water scarce or unreliable.

Secondary Process

Filters

Trickling Filters/Percolating Filters



Source: After Mann, H. T., Williamson, D., 1982

Technology Description:

Trickling filters follow the same principle as the anaerobic filter as it provides a large surface for bacteria to settle, however it is an aerobic process. The Trickling filter consists of either a rock or gravel medium filling the filters. The organic pollution in wastes is consumed by organisms that grow in a thin biological film over the rock or gravel medium. Oxygen is obtained by direct diffusion from air into the thin biological film. Preliminary settlement of sewage is required after which it is dosed by mechanical means over the surface of the filters. To ensure that bacteria are allowed equal access to air and wastewater, wastewater is dosed in intervals to allow time for both wastewater and air to enter the reactor. Wastewater also needs to be equally distributed over entire surface to fully utilise the media in filter.

Effluent quality is 80% BOD removal with organic loading rates of 1kg BOD/m^3 x d

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

- Bacterial film has to be flushed away regularly to prevent clogging and to remove dead sludge.

Advantages:

- High effluent quality

Disadvantages / constraints:

- High operation and maintenance require-ments
- Needs electical power

Relative Cost:

- High Cost

Cultural Acceptability:

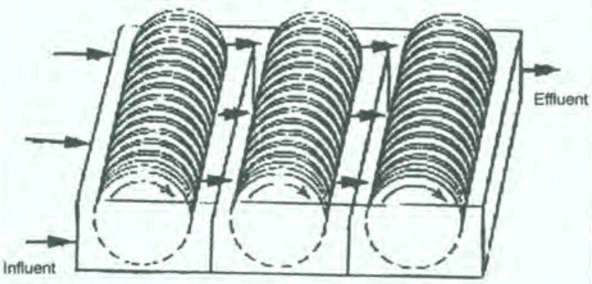
- Is generally not well accepted within the region

Suitability:

- Since only receive liquid waste not suitable where water scarce or unreliable.
- Requires a high volume of water.

Secondary Process

Rotating Biological Contactor (RBC)



Technology Description:

An RBC (also referred to as a biodisc) operates on a similar principle to the trickling filter, but has a rotating bed of attached bacteria which is immersed in a tank of wastewater. The rotation exposes the surface of the disc to the atmosphere permitting aeration, and then resubmerges it in the wastewater. The bed comprises a number of circular discs made of styrofoam, high-density plastic, or other lightweight material, closely spaced together and mounted on a rotating drive shaft. The discs rapidly develop a microbial community in the form of a film 3 mm thick and this film is responsible for BOD removal. Full-scale RBC's may have discs up to 7m in diameter mounted on 7m shafts. Rotation speeds are usually between 1 and 2 rpm. The power to rotate a shaft ranges from 2 to 4 KW per shaft.

Loading rates from 0.8-1.2 Kg soluble BOD5/100 m^2/day are recommended.

Current Extent of Use:

- Marketed as a package plant for small communites such as hotels

Operation and Maintenance:

- Ease of operation and low land requirement

Advantages:

- Reduced power and maintenance costs
- Stability against hydraulic shock loadings.
- Capability of achieving a high degree of carbonaceous and nitrogenous BOD removal

Disadvantages / constraints:

- Still a relatively novel process
- Breaking/cracking of discs and regular shaft bearing failure
- Lack of operational control

Relative Cost:

- Lower costs compared to activated sludge systems

Cultural Acceptability:

- Accepted generally in the region

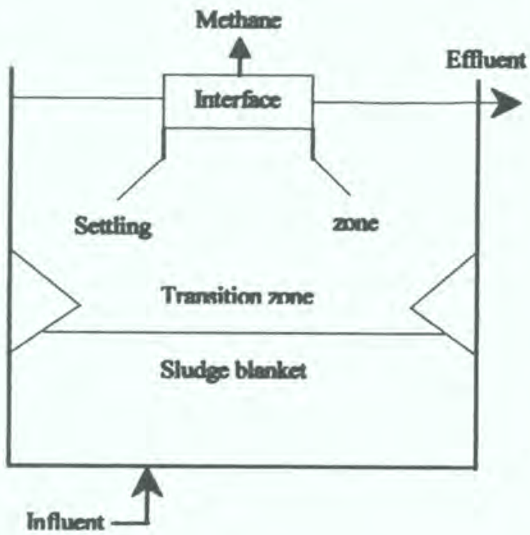
Suitability:

- Suitable for application in developing countries

Secondary Process

High Rate Anaerobic Treatment Process

The Upflow Anaerobic Sludge Blanket (UASB)



UASB REACTOR

Technology Description:

This process is suitable for all kinds of wastewater including domestic. The UASB maintains a layer of active anaerobic sludge suspended in the lower part of the digestor. The upflow velocity keeps the sludge blanket in place. Their unique feature is a solids seperation system which retains a high solids fraction in the reactor, thus permitting higher loading rates and lower retention times than are usually associated with anaerobic systems. After weeks of acclimatisation and maturation a well settling (and often granular in nature) sludge forms which improves the stabilty of the blanket and helps in applying high loading rates. It is not unusual for UASB 's to operate with HRT's of as low as 6 hours treating wastes with a COD>> 5000 mg/l.

For sewage treatment, HRT's of 10 to 12 hours are commonly used with COD removal efficiencies of 70 to 80%.

Current Extent of Use:

- Not currently used in the region

Operation and Maintenance:

- Relatively simple to operate and maintain

Advantages:

- Low Cost
- Low land requirement
- Moderate operation and maintenance required
- Recovery of biogas which can be used as a fuel

Disadvantages / constraints:

- Needs time to cultivate a good sludge
- Water supply must be adequate in the region

Relative Cost:

- Low to moderate cost

Cultural Acceptability:

- Should be easily acceptable in the region

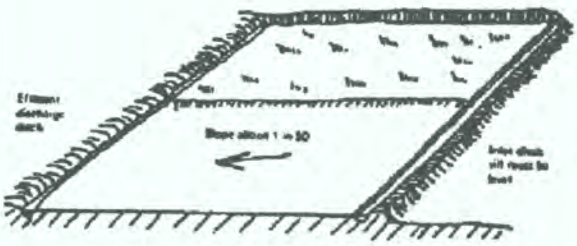
Suitability:

- Suitable where water supply is adequate and reliable.

Tertiary Process

Lagoons/Plots

Grass Plots



Source: After Mann, H. T., Williamson, D., 1982

Technology Description:

Grass plots are simple to construct with high rates of removal. Plots should be even and sloped towards collection areas. Basically effluent passes through the mesh of the grass blades which then filter out solids in a well-aerated environment. The possibility of contamination of groundwater should be considered, as some effluent will percolate into porous ground. Coarse natural grass is satisfactory. Surplus grass needs to be removed and cuttings should be disposed of properly as there could be danger of further pollution as they decompose.

Typical treatment quality performed on secondary treated effluent is 50% BOD removal, 70% Suspended solids removal, 90% E. Coli removal.

Current Extent of Use:

- Limited used in the region

Operation and Maintenance:

- Requires removal of solids but only when they are seen to physically prevent the flow
- Surplus grass needs to be removed

Advantages:

- Simple to construct.
- Low operation and maintenance
- Construction material available locally
- No electrical requirement
- High Effluent Quality

Disadvantages / constraints:

- High land space required
- Possible water contamination from runoff
- High volume of water required

Relative Cost:

- Moderate

Cultural Acceptability:

- Is generally not well accepted in the region

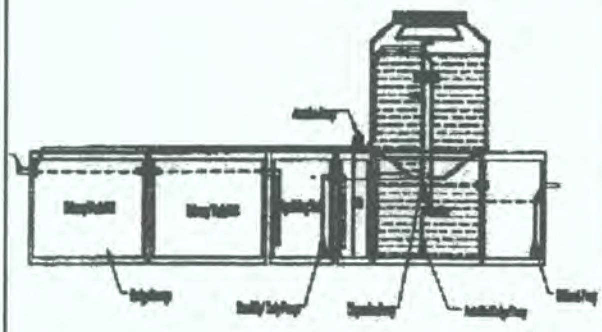
Suitability:

- Since only receive liquid waste not suitable where water scarce or unreliable.

Package Plant Types

Plant Type

Enviroflow Biofilter Treatment Plan System



Source: After Enviroflow Wastewater Treatment Brochure

Technology Description:

Enviroflow Plants treat both black and greywater through a two-stage bacterial digestion process followed by clarification and disinfection. Essentially wastewater is run from kitchens, toilets etc. through two treatment stages before clarification and disinfection. The first stage is carried out using anaerobic and aerobic bacteria inside a primary tank. Solids undergo digestion by bacteria and liquids containing soluble organic matter then passes to the second stage. The second stage has a biological trickling filter in which selected bacteria grow on a medium where wastes flow in contact with the air. Any bacterial cell matter that is separated in this step is kept in the effluent stream and allowed to settle out in the clarifying chamber. Following this the then clear effluent is passed to a disinfecting step where Chlorine is used to disinfect the effluent. The plants are capable of servicing from just 10 people to communities of 20,000 people as plants can be modified to suit such varying populations.

Typical effluent quality contains BOD5 <20mg/l and Suspended Solids <30mg/l

Current Extent of Use:

- Not currently used in the region

Operation and Maintenance:

- Manual provided for operation and maintenance
- Small pill kit tester for effluent monitoring

Advantages:

- Low land space required
- High effluent quality

Disadvantages / constraints:

- High volume of water requirement
- High operation and maintenance
- Requires electricity

Relative Cost:

- High

Cultural Acceptability:

- Should generally be accepted within the region

Suitability:

- Since only receive liquid waste not suitable where water scarce or unreliable.

Package Plant Types

Plant Type

Sequential Batch Reactors Cromaglass Unit

Source: After Cromaglass Wastewater Treatment System

Technology Description:

The Cromaglass Systems are essentially Sequencing Batch Reactors where treatment is by timed sequences within a single vessel. The unit consists of 3 sections each performing a different task. In the first section (A) and aeration occurs (Solids Retention). This section is separated from the rest of the unit by a non-corrosive screen, which retains inorganic solids. Organic solids are broken up by turbulence created with mixed liquor being forced through the screen by a submersible aeration pump. Section (B) is the continuing Aeration section where air and mixing are provided by pumps. An optional denitrification is performed by creating anoxic conditions by closing off air to air intake pumps thus stopping aeration but allowing continual mixing. The liquid is then transferred to section (C) the Clarification Section. When the clarification section is overfilled excess is spilled back into the aeration section. When this stops the clarifier is then isolated, solids settle and separate after which effluent is pumped out of the Clarifier for discharge. Sludge is removed to a sludge processing unit.

Treatment achieves over 90-95% reduction of BOD and Suspended Solids. The resulting effluent quality has BOD_5 - 30mg/L, Total Suspendable Solids 30mg/L.

Current Extent of Use:

- Not currently used in the region

Operation and Maintenance:

- High operation and maintenance.
- High technology requiring

Advantages:

- Low land space required
- High effluent quality

Disadvantages / constraints:

- High operation and maintenance
- Requires electricity
- High technology requiring Skilled operation and Maintenance.

Relative Cost:

- High

Cultural Acceptability:

- Should be acceptable in the region

Suitability:

- Since only receive liquid waste not suitable where water scarce or unreliable.

4.5 Wastewater Reuse

The reuse of wastewater in agriculture and aquaculture has much potential and is used throughout the world. It can replace the use of limited freshwater for the irrigation of crops or be used as an additional source of nutrients to increase production of horticulture and forestry crops. Aquaculture is becoming popular and may provide additional economic opportunities in developing countries. Nutrients found in wastewater discharges, that normally pollute the environment, are beneficial when used with irrigation and aquaculture applications. However the reuse of wastewater is currently not widely practised in the region. With many countries experiencing limited water resources the reuse of wastewater would provide benefits through both conserving water and reducing pollution potential to marine and surface water resources. Countries seeking to provide appropriate and affordable sanitation facilities should explore all possibilities to reuse wastewater wherever possible.

In many countries there are strong traditional feelings against the reuse of wastewater. Much talking and convincing may be required to introduce this concept. The issue of 'most appropriate' technology needs to be explored and thoroughly discussed with potential users before proceeding with any new development.

Wastewater is a valuable resource and its reuse in the horticulture, forestry and aquaculture industries should be encouraged. Reduction in environmental pollution as well as increased production would result. However adequate health safeguards are required regarding wastewater treatment, crop restriction, appropriate application methods and human exposure control. The WHO (1989) *Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture*, should be consulted to ensure that any reuse of wastewater is safe for those who use reused wastewater and those who consume food products grown with reused wastewater. (ie eating contaminated crops or eating animals that have fed on contaminated crops or developed in wastewater ponds).

For additional information on the reuse of wastewater visit the Integrated Bio-System Network at http://www.ias.unu.edu/proceedings/icibs/ibs/ibsnet/. This is a network of people, connected via the Internet, for forum and cooperation in the application of integrated bio-systems in agriculture, industry, forestry and habitat.

Wastewater Reuse

Technology Description:

The technology for water reuse is a combination of existing wastewater treatment technologies and water supply treatment technologies. Processes under the general heading of wastewater reuse range from the most sophisticated and complex engineering processes to some of the simplest, natural systems. Detailed descriptions of these technologies can be found in general literature on wastewater treatment, but, for purposes of wastewater reuse, the type of wastewater; the potential use of the reused water (for potable uses or non-potable uses); capital and operating costs; and, existing local facilities and skills for the maintenance and operation of the selected facility.

Effectiveness of the Technology:

This technology can produce large quantities of low quality water, which can be used to service high water consumptive uses such as irrigation. This use conserves the available freshwater resources for more essential purposes such as domestic use. On a small scale grey water and septic tank effluent can be used to irrigate, lawns and gardens without much cost.

Current Extent of Use:

Not used much in the region

Level of Involvement

This technology requires engineers and highly skilled plant operators for both construction and operation of reuse facilities.

Operation and Maintenance

Wastewater treatment facilities require a high level of operation and maintenance, and close monitoring of discharge effluent quality to minimise health and environmental risks associated with wastewater reuse.

Advantages

Wastewater reuse conserves freshwater resources, by making use of the potentially large volumes of low quality water for irrigation and similar uses.

Disadvantages

Wastewater reuse carries a potential public health risk when directly reused for potable use or indirectly reused to irrigate crops that are commonly eaten without cooking (e.g. vegetable crops such as tomatoes and most fruit crops). Consumers may also be unwilling to use treated wastewater for agricultural and domestic uses. Variations in wastewater flows and composition may lead to variable quality of the treated water for irrigation use. Close monitoring of the treatment processes by skilled staff is required.

Costs:

High

Cultural Acceptability:

Some cultures may have a problem with using wastewater to irrigate food crops

Suitability:

The potential for wastewater reuse on small islands may be limited for a number of reasons. On very small islands, there may be insufficient land for agriculture or industry. This limits the amount of potential wastewater as well as the potential for its reuse; some small islands may not have a suitable source of wastewater. If seawater flushing is already used in sewage systems as a means of conserving freshwater, the resultant wastewater cannot be used. Notwithstanding, opportunities do exist for the use of wastewater on a small scale. For instance, tourist resorts can make use of treated wastewater from package treatment plants to irrigate gardens and lawns (UNESCO, 1991).

4.6 Wastewater Disposal Systems

The two main options for wastewater disposal are either into a body of water, through outfalls or on/into the land. In most countries of the region the sea is the main end point for wastewater disposal, either directly through piped outfalls or indirectly through groundwater discharges. For each of these options it is preferred that the wastewater has been treated to remove at least solids and grit that may cause blockages compounding the operation and maintenance of the system, and causing visible pollution in receiving water bodies.

Outfalls

Detrimental effects to the environment from areas that are sewered, with various degrees of treatment, may be minimised by using good effluent disposal practices. The location of ocean outfalls ideally should be beyond the reef, in high circulation areas, and below the thermocline. While a few systems do meet some of the criteria, no outfall disposal system in the Region meets all these criteria. All too often outfall locations are chosen based on other criteria (i.e. treatment plant or pump station locations) instead of using criteria that safely dispose of wastewater to minimise environmental effects. These basic design criteria should be investigated before the construction of any new system or the upgrading of an existing system to avoid problems that are currently being experienced by many countries.

While outfall disposal is still economically attractive, if not located and constructed properly, they may cause much environmental pollution of coastal areas that may have significance health, culture and economic consequences.

Discharges to rivers should not be allowed unless a high degree of initial wastewater treatment, river mixing and dilation is achieved.

Land Disposal

Land disposal methods include rapid infiltration, slow rate infiltration and overland flow. All involve the application of wastewater to land, and rely on various degrees of percolation through the soil, evaporation, and transpiration to renovate the wastewater. The following tables compare the requirements of each land disposal method:

Table XIV Land Disposal Methods (Source: Opus Environmental Training Centre, Principle and Trends in Wastewater Treatment Manual (1998))

Feature	Slow Rate	Rapid Infiltration	Overland Flow
Application Technique	Sprinkler or Surface[a]	Usually Surface	Sprinkler or Surface
Annual Loading Rate, m	0.5 - 6	6 - 125	3 - 20
Field Area Required, ha[b]	23 - 280	3 - 23	6.5 - 44
Typical Weekly Loading Rate, cm	1.3 - 10	10 - 240	6 - 40
Minimum Preapplication Treatment Recommended in the US	Primary Sedimentation[d]	Primary Sedimentation[e]	Grit Removal and comminution[e]
How the Wastewater is Removed from the Soil	Evapotranspiration and Percolation	Mainly Percolation	Surface Runoff and Evapotranspiration with some Percolation
Treatment Effectiveness	Excellent	Very Good	Fair
Need for Vegetation	Required	Optional	Required
Suitable Soil Types	Loamy, Medium Textured. Sandy with certain crops	Sandy/Loamy Soils	Fine Textured Soil

a Includes ridge and furrow and border strips

b Field area in hectares not including buffer area, roads of ditches for 3,785m³.day/flow

c Range includes raw wastewater for secondary effluent, higher rates for higher level of preapplication treatment.

d With restricted public access; crops not for direct human consumption

e With restricted public access

Table XV- Comparison of Typical Effluent Qualities from Land Disposal Methods (Source: Opus Environmental Training Centre, Principle and Trends in Wastewater Treatment Manual (1998))

Treatment System	Biological Oxygen Demand (mg/L)	Suspended Solids (mg/L)	Total Nitrogen (mg/L)	Phosphorus (mg/L)
Rapid Infilteration	<5	<5	10	2
Overland Flow	5	10 - 20	30	4
Slow Rate	1	1	5	<1

The application of wastewater to land may be by:

Surface flow: Wastewater is applied at one end of an area and allowing it to spread to the other end by gravity. Runoff control maybe a problem.

Sprinkler distribution: Wastewater is applied by over ground sprinklers (either stationary or moving) Normally pumping is required and as a result aerosols may be produced.

Subsurface and localised irrigation: This includes the use of drip and trickle irrigation methods which require a good quality effluent to avoid clogging. Using these methods could reduce microbial contamination of crops.

The following table provides information on selecting a suitable application method for land disposal of wastewater.

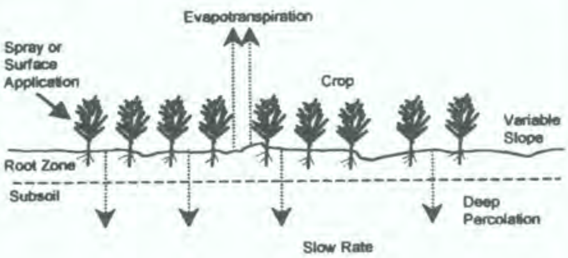
TableXVI - Factors affecting choice of irrigation method, and special measures required when wastewater is used. (Source: Mara and Cairncross, (1989))

Irrigation Method	Factors Affecting Choice	Special Measures for Wastewater
Border (flooding) irrigation	Lowest cost, exact levelling not required	Thorough protection for field workers, crop-handlers and consumers
Furrow irrigation	Low cost, levelling may be needed	Protection for field workers, possibly for crop-handlers and consumers
Sprinkler irrigation	Medium water use efficiency, levelling not required	Some crops, especially tree fruit, should not be grown. Minimum distance 50-100m from houses and roads. Anaerobic wastes should not be used because of odour nuisance
Subsurface and localised irrigation	High cost, high water use efficiency, higher yields	Filtration to prevent clogging of emitters

Land Disposal

Land Treatment

Slow Rate Process



Technology Description:

The processes of land treatment are selected mainly on the basis of soil permeability of the treatment site. Prior to land treatment there needs to be preliminary treatment through either screening, grit removal or primary sedimentation to reduce soil clogging and to prevent nuisance conditions from occurring. Slow rate process requires a soil permeability of 5 to 50mm/hr and a depth of a minimum of 1m to groundwater. It should be in a site with a clay loam to sandy loam soil type with a slope of less than 15% for cultivated land and less than 40% for forested land. Disposal of effluent can be through evapotranspiration and percolation. There is a need for vegetation with Slow Rate Process.

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

-

Advantages:

- Low operation and maintenance
- No electrical requirement
- Constuction material locally available

Disadvantages / constraints:

- High land space required

Relative Cost:

- Moderate

Cultural Acceptability:

- Is generally accepted within the region

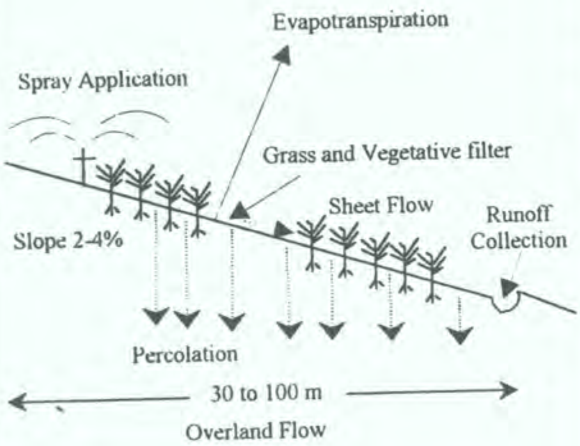
Suitability:

- Since they only receive liquid waste they are not suitable where water supply scarce or unreliable
- Requires high volumes of water for transportation to treatment site.

Land Disposal

Land Treatment

Overland Flow Process



Technology Description:

This is also a land treatment process and requires preliminary treatment of grit screening etc. In overland flow process the soil permeability should be less than 5mm/hr. The depth to groundwater is not critical and the soil type should be either clay, silts and soils with impermeable barriers, the slope of the area being between 1-8%. Surface runoff and evaporation with some percolation can dispose of the effluent. There is a need for vegetation in overland flow process.

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

-

Advantages:

- Low operation and maintenance
- No electrical requirement
- Constuction material locally available

Disadvantages / constraints:

- High land space required

Relative Cost:

- Moderate

Cultural Acceptability:

- Is generally accepted within the region

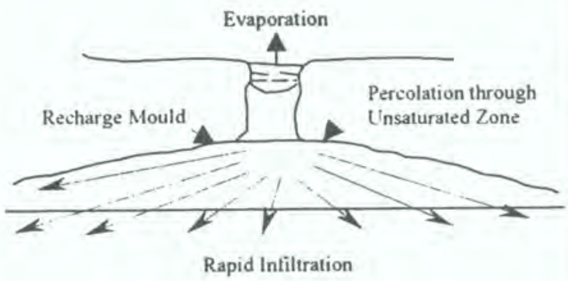
Suitability:

- Since they only receive liquid waste they are not suitable where water supply scarce or unreliable
- Requires high volumes of water for transportation to treatment site.

Land Disposal

Land Treatment

Rapid Infiltration Treatment Process



Technology Description:

Rapid Infiltration Land Treatment process also needs to be preceded by preliminary treatment in order to reduce soil clogging and prevent nuisance conditions from occurring. This treatment process can only be used in soils having a permeability of greater than 50mm/hr. The depth to groundwater should be a minimum of 3m in sandy or sandy loam soil types. The disposal of effluent is done mainly through percolation.

Typical treatment quality achieved is 86-100% BOD removal, 100% suspended solids removal dependent on several factors e.g. rest cycles, and/or cleaning, 10-93% nitrogen removal, 29-99% phosphorus removal

Current Extent of Use:

- Limited use in the region

Operation and Maintenance:

-

Advantages:

- Low operation and maintenance
- No electrical requirement
- Constuction material locally available
- High effluent quality

Disadvantages / constraints:

- High land space required

Relative Cost:

- Moderate

Cultural Acceptability:

- Is generally accepted within the region

Suitability:

- Since they only receive liquid waste they are not suitable where water supply scarce or unreliable
- Requires high volumes of water for transportation to treatment site.

4.7 Industrial Wastewater Treatment Systems

Industry is typically faced with two choices: direct discharge to surface waters or discharge to the sewer system, if one is available. Effluent standards will apply to both options: sewer regulations will require pre-treatment in order to remove toxics but effluents which can be treated by normal municipal systems will be accepted, at charge.

Because of the economies of scale, sewer discharge of simple wastes such as BOD will often be cheaper than industrial on-site treatment. However, there are often problems with the capacity of the municipal treatment or with implementing the correct charging systems and this option may not always be available.

Industrial wastewaters are subject to wide variations of both flow and load. Moreover, rarely do any two factories produce similar effluents. As manufacturing plants become older they tend to produce more polluted wastewaters as there is greater leakage from the manufacturing operations. The older manufacturing plants are likely to have been designed to use more water and power. To encourage the discharge of materials to the drainage system and to have been subject to modifications, all of which produce a wastewater which will be more costly to treat. These difficulties, combined with management attitudes which class pollution control equipment as "non-productive", make it difficult to provide reliable effluent quality. It is only by adopting an integrating approach to combine the manufacturing and pollution control operations that an industry can be fully optimized.

Figure 3 shows a typical train for industrial wastewater treatment. At the heart of any treatment system for an industrial wastewater there will be a biological treatment system. Eckenfelder et al.(1989) have produced an algorithm for the selection of biological treatment system, but it is based solely on the characteristics of the wastewater and the objectives of the treatment system (Figure 4).

Figure 3: Typical sequence of events for treating an Industrial Wastewater

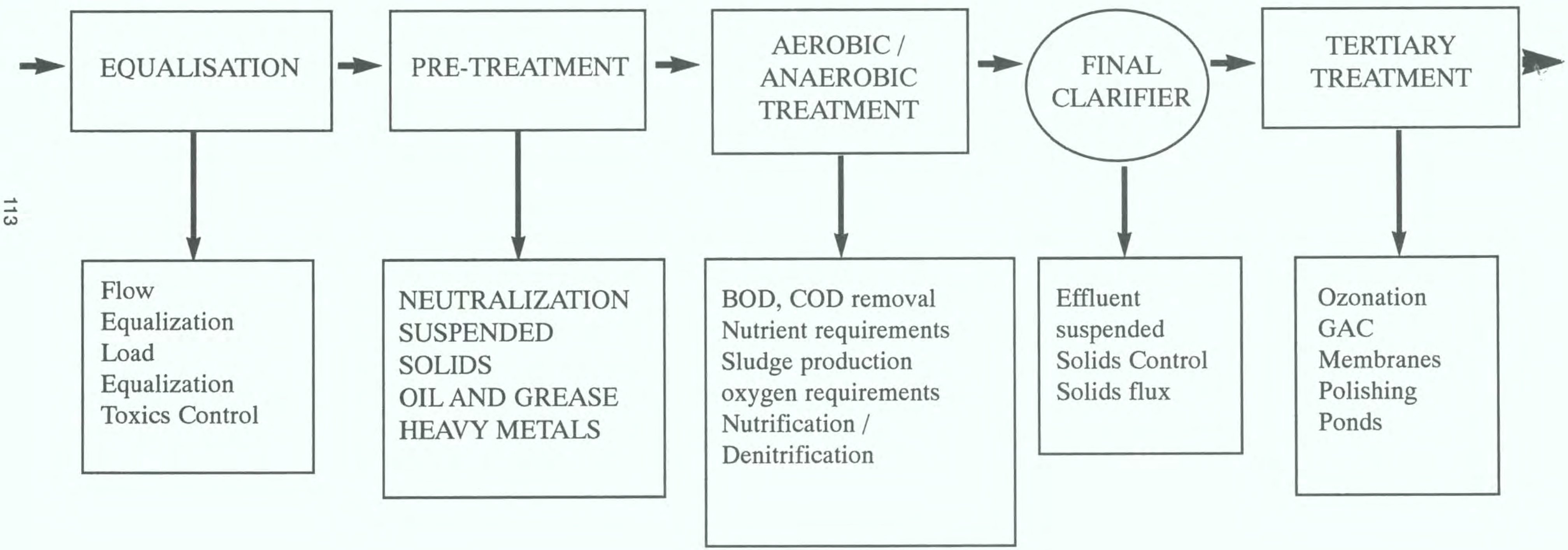
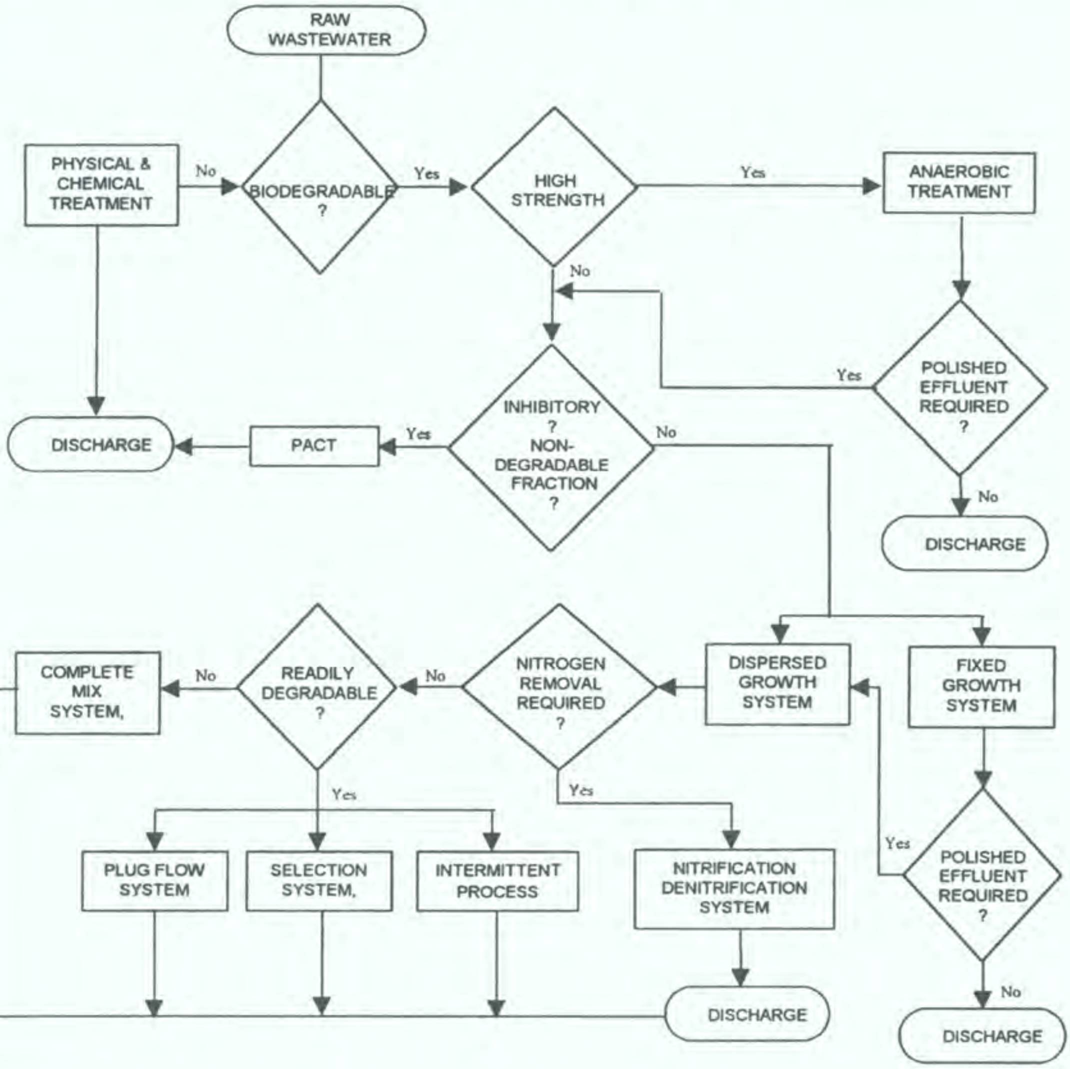


Figure 4: AN ALGORITHM FOR THE SELECTION OF BIOLOGICAL TREATMENT SYSTEMS

(from Eckenfelder et al., 1989)



4.8 Optimizing wastewater treatment

The major components of a wastewater management plan in a river basin, which typically compete for investment funds are:

- Upgrading of sewer systems in existing urban areas
- Upgrading of municipal treatment systems
- Introduction of a system to identify and regulate discharges from industry
- Reduction of current industrial pollution loads through recycling, improved waste management, on-site treatment or connection to sewer systems
- Adequate provision of sewerage and treatment for new urban development
- Development of programs to quantify and tackle non-point sources of pollution, including sewer overflows.

The cost of those components must be considered in terms of both the overall costs and the distribution of those costs. In this way an estimate can be made of the most cost-effective investments to achieve water quality objectives in a river basin.

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- Basel Convention: http://www.unep.ch/sbc
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