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A 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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A 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

Compiled by OPUS International

in conjunction with the

South Pacific Regional Environment Programme (SPREP)

and the

South Pacific Applied Geoscience Commission (SOPAC)

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South Pacific Applied Geoscience Commission (SOPAC)
Suva, Fiji Islands

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PREFACE

As highlighted in the 1994 Barbados Programme of Action, waste management is a major area of concern for Small Island Developing States (SIDS). SIDS, like other developing countries, have problems with the management of waste. However, SIDS experience additional constraints arising from small land areas, high dependence on imports and high population densities exacerbated by high tourist inflows. Because of limited access to appropriate technologies, on many occasions 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, with or without adaptation, could be applied in similar situations. Unfortunately, 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.

UNEP, in partnership with SIDS regional institutions, embarked on a programme to improve the access of SIDS to appropriate technology. A draft directory containing technologies found to be appropriate for SIDS from practical experience as well as literature review was compiled. It was subjected to peer review at a global level by experts from regional SIDS institutions (Caribbean, Indian, Mediterranean and Atlantic Ocean SIDS (IMA/SIDS) and Pacific), UN agencies, the Commonwealth Secretariat as well as universities. The review was made at 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 experts found the technologies to be appropriate to SIDS and recommended that each SIDS region further reviews and adapts the technologies according to their conditions.

The IMA/SIDS region adapted the technologies to suit their conditions and published the *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.* This document '*A 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*' is the result of a review of the original directory by national experts from the Pacific Island Countries in Majuro, in October 2001.

This publication is part of UNEP collaboration with SIDS on the implementation of the Waste Management chapter of the Barbados Programme of Action. Through this initiative a series of publications have been made. The first publication in 1998 was the *Guidelines for Solid Waste Management in the Pacific* developed in collaboration with the South Pacific Regional Environment Programme (SPREP). The second was in 1999, *The Strategic Guidelines for Integrated Waste Management in SIDS.* These are planning guidelines developed with input from all SIDS regions and subjected to intensive peer review. The guidelines are based 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.

The third document included in the UNEP waste management series is the *IMA-SIDS Waste Management Strategy with special emphasis on Minimisation and Resource Recovery*. These were developed with input from national experts in the region and adopted by the governments in the 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 Pacific region, 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.

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We also acknowledge the contribution made by the Commonwealth Secretariat and representatives from the Indian, Mediterranean, Atlantic Ocean and Caribbean regions during the review of the technologies in London, from 2 to 5 November 1999. Our appreciation is also extended to the national representatives from American Samoa, Cook Islands, Federated States of Micronesia, Fiji Islands, Kiribati, Marshall Islands, Nauru, Niue, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu for reviewing the Directory in Majuro, Marshall Islands, October 2001.

ACRONYMS

ACP countries	:	African, Caribbean and Pacific countries
ADB	:	Asian Development Bank
ASPA	:	American Samoa Power Authority
BOD	:	Biological Oxygen Demand
COD	:	Chemical Oxygen Demand
CT	:	Composting Toilet
DVC	:	Double Vault Composting.
EST's	:	Environmentally Sound Technologies
FSM	:	Federated States of Micronesia
GCL	:	Geosynthetic Clay Liner
GW	:	Groundwater
HRT	:	Hydraulic Retention Time
MSWM	:	Municipal Solid Waste Management
MSW	:	Municipal Solid Waste
NZODA	:	New Zealand Official Development Assistance
PCB's	:	Polychlorobiphenyls
PIC's	:	Pacific Island Countries
POPs	:	Persistent Organic Pollutants
PVC	:	Polyvinyl Chloride
RDF	:	Refuse Derived Fuel
ROEC	:	Reed Odourless Earth Closet
SANEX	:	Sanitation Expert Systems.
SIDS	:	Small Island Developing States
SOPAC	:	South Pacific Applied Geoscience Commission
SPREP	:	South Pacific Regional Environmental Programme.
SS	:	Suspended Solids
UNEP-IETC	:	United Nations Environment Program–International Environmental Technology Centre
UNESCO	:	United Nations Education, Scientific and Cultural Organisation.
UNHCS Habitat	:	United Nations Centre for Human Settlements
VIP	:	Ventilated Improved Pit
WHO	:	World Health Organisation
WM	:	Waste Management

1 Introduction

1.1 Background

Small Islands have special physical, demographic and economic features. Their much reduced areas, shortage of natural resources (arable land, freshwater, minerals and conventional energy sources), geological complexity, isolation and widespread nature of their territories, exposure to natural disasters (typhoons, hurricanes, cyclones, earthquakes, volcanic eruptions and tsunamis) sometimes make the water resources, solid waste and wastewater problems of these islands very serious (UNESCO, 1991).

The need for waste management in the Pacific Island Countries (PICs) was small for most part of the last centuries as most waste products were biodegradable and populations were dispersed. Commonly, wastes were disposed of through individual dumping in lagoon and rivers or on unused land close to villages. Over the last decade, the region urbanized at a very fast rate that the governments could not keep pace with facilities and services making the disposal of wastes, both solid and liquid difficult. Urban population rose from 20.4 % to 24.9 % in 1995 (United Nations Populations Division, 1996) and the trend is continuing. The result of this rapid expansion is the pollution of water resources, difficulty in disposing of solid and human wastes, increasing diseases related to poor and unsanitary living conditions such as respiratory and gastro-intestinal complaints. Diseases related to water supply and sanitation are prevalent especially in the informal settlements where dwellers are living in marginal areas with inadequate waste disposal, potable water and sanitation systems (Pacific Environment Outlook 1999).

The rapid urban population and increasing imports of non-biodegradable material and chemicals related to agriculture and manufacturing have rapidly brought about a confrontation with the realities of management of toxic and hazardous substances. All PICs now share the problem of disposal of waste and the prevention of pollution. In major towns, the search for environmentally safe and socially acceptable sites for waste disposal has become a perennial concern that needs a sustainable solution. Inadequate sanitation for the disposal or treatment of liquid wastes have resulted in high coliform contamination in surface waters and in groundwater in urban areas. Pollution by toxins from industrial wastes, effluent from abattoirs or food processing plants, biocides and effluent from sawmills has also been reported.

According to the Pacific Environment Outlook (1999), the areas of concern in the Pacific region until 2010 include the environmentally sound management of solid and liquid wastes, toxic chemicals and hazardous wastes. Particular effort is required at the national level to strengthen the capacity of island countries to minimize and prevent pollution. In the long term because of the land constraints of islands, cost- effective disposal options are limited. Pacific island countries will need to focus on reusing, recycling and minimizing wastes and the use of technology appropriate to islands in order to manage the waste generated.

Most SIDS do not have access to appropriate waste management technologies. Because of this constraint, on many occasions, 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, with or without adaptation, could be applied in similar situations. There are numerous waste management technologies used throughout the world. Many of these technologies have been used in the Pacific, but have failed for a range of different reasons. Some of the reasons for failure include being an inappropriate technology, having insufficient operation and maintenance input, and a lack of funding and/or skilled personnel. Unfortunately, the information has not been shared with other SIDS in the same region or in other regions. Hence the need for this directory which compiles a list of practical technologies applicable to the Pacific SIDS.

Waste management has been identified as a high priority area by PICs (Pacific Environment Outlook 1999). It is also one of the 14 priority areas of the Barbados Programme of Action. The Waste Management chapter of the Programme of Action urges SIDS to 'introduce clean technologies and treatment of wastes at the source and appropriate technology for solid waste treatment' and the international community to 'support the strengthening of national and regional capabilities to carry out pollution monitoring and research and to formulate and apply pollution control and abatement measures'. The need to transfer environmentally sound technologies (EST) and improve co-operation and building capacity within developing countries was underscored in Chapter 34 of Agenda 21. Improved access to information on environmentally sound technologies has been identified as a key factor in transferring technologies to developing countries.

In response to the Barbados Programme of Action, the Twentieth Session of the United Nations Environment Programme (UNEP) Governing Council adopted decision GC20/19 which invited the UNEP Executive Director to 'prepare guidelines and programmes for waste minimization, reduction treatment and disposal applicable under the constraints of small island developing States'. This directory is part of UNEP's efforts to assist SIDS in the management of wastes.

1.2 **Purpose of the Directory**

This Directory on Environmentally Sound Technologies for Waste Management in the Pacific Small Island Developing States (SIDS) focuses primarily on proven sound environmental technologies for waste management plus those currently successfully being used in SIDS within the Pacific Region.

In addressing each broad waste management topic, sound practices are also provided, based on lessons learnt from the past. These sound practices give guidelines for selection of the most appropriate of the technologies listed for a given application. These sound practices can also be used to evaluate any existing or new technologies that arise in the future that are not listed in this directory.

Note that the technologies presented in this Directory are also applicable to Small Island Developing States in other Regions.

1.3 Structure of the Directory

The Directory is divided into 3 major parts, which include

- Solid Waste Technologies

  Discusses information on different Municipal Solid Waste Management (MSWM) technologies that are currently used in different regions of the world, and gives a guide as to which of these are economically feasible, and Environmentally Sound Technologies (ESTs).

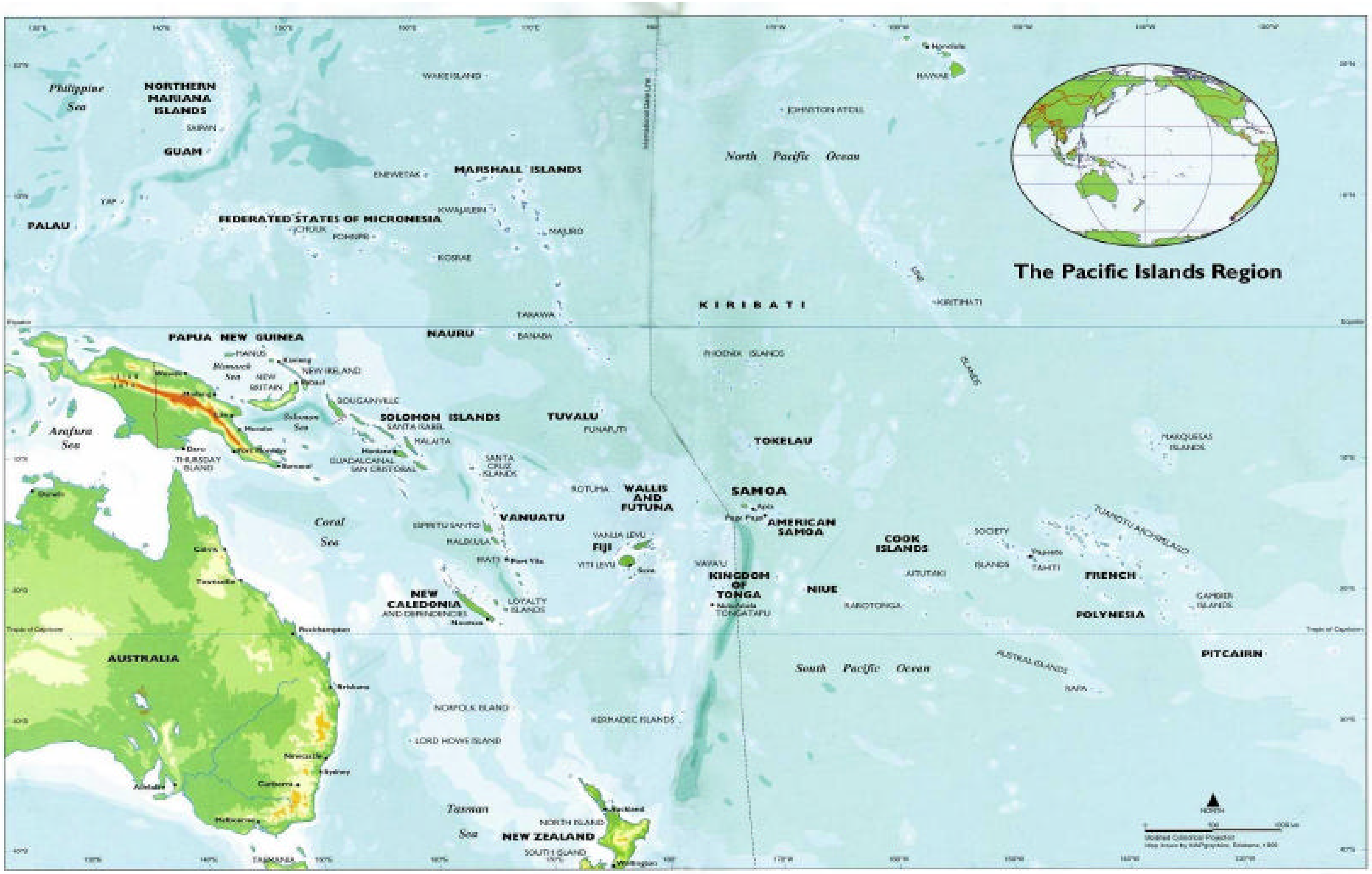
- Hazardous Waste Technologies

  Addresses the proper management of various types of hazardous wastes, as they require special handling, treatment and disposal due to their hazardous potential.

- Liquid Waste or Wastewater Technologies

  In SIDS wastewater disposal systems are just as important for public health as a water supply distribution system. This section discusses various wastewater treatment and disposal technologies from on-site systems to centralised and decentralised systems.

The Directory is a simple guide, which tries to convey technical issues in an easy and understandable manner and is a UNEP initiative to assist SIDS in addressing waste management issues



Source: Map Graphics, Brisbane, 1996.

2 Solid Waste Technologies

2.1 Introduction

Prior to the introduction of imported goods, and packaging, the waste produced from a typical Pacific Island was entirely organic in origin, and could be broken down or composted without thought or problem. To varying degrees, the majority of Pacific Islands 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, SIDS have not been aware of the need, or have not been able, to developed suitable waste management systems to cope with these changes in waste character.

ESTs are therefore needed for the Pacific Islands 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 wastes.

In 1996, the United Nations Environment 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 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 ESTs.

The task of identifying ESTs is complicated by the fact that what constitutes an EST is highly dependent on the environmental, economic, climatic, cultural, 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 Pacific Region. As was done in the International Source Book, this directory, focused on the Pacific Region, is structured around 6 separate topics of waste management. These 6 topics relate directly to the physical materials, and processes of waste management. These topics are:

1. Waste Reduction
2. Collection
3. Composting
4. Incineration
5. Landfills
6. Special wastes (These are covered in Section 3 Hazardous Wastes)

Other issues relating to overall waste management are waste characterisation, management and planning, training, public education and financing. These issues are dealt with in the guidelines section of this document.

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

2.1.1 What is a Sound Practice?

Before identifying (ESTs) for the Pacific Region, the question needs to be asked, "What is a "sound" practice for Waste management?" The UNEP (1999) *International Source Book on Environmentally Sound Technologies for Wastewater and Stormwater: Pacific Regional Overview of Small Island Developing States*, 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 Pacific 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 the Pacific, these background conditions (which tend to make solid waste management difficult) include:

- high population density on some small islands accelerated by high growth rates;
- small population numbers spread over many small islands;
- high tourist numbers;
- lack of funding from within SIDS governments;
- poor planning;
- limited area to deal with waste absorption capacity;
- low levels of training; 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 Pacific Region, and hence whether they are "sound". The following are criteria used by the UNEP in their International Source Book for evaluating technologies and policy.

2.1.2 Criteria for Evaluating 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 benefits, and costs of the option?

- Could the environmental soundness of the option be significantly enhanced, given a small increase in cost?
- Conversely, would it be possible to significantly reduce the cost, with only a small detriment to the environment?

(e) Is the practice administratively feasible and sensible?

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

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

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

2.1.3 Background Conditions that affect the selection of an EST in the Pacific Region

As already discussed, there are many factors which help determine what should be considered a sound practice within a particular situation. The following is a summary of the background conditions typical in SIDS of the Pacific Region. For this summary, information is based on background conditions of the following Islands:

- Rarotonga in the Cook Islands;
- Funafuti in Tuvalu;
- Tarawa in Kiribati;
- Niue;
- Pohnpei in Micronesia;
- Port Vila in Vanuatu; and

- Majuro in the Marshall Islands.

Information has also been drawn from reports on waste issues in the African, Caribbean and Pacific (ACP) countries. These include:

- Fiji;
- Papua New Guinea;
- Samoa;
- Solomon Islands; and
- Tonga.

However, generally, most of the technologies presented would be suitable for all SIDS.

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

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 due to human activities:

- The waste characteristics including density, moisture content, combustibility, recyclability, and presence of hazardous waste in Municipal Solid Waste (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 women and the poor) in carrying out MSWM activities.
- Social and cultural practices.

2.2 Waste Reduction

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

- increased demand for imported packaged goods due to rapid urbanisation, with related rise in standard of living expectations;
- isolation of islands from potential markets for recycled materials;
- lack of waste reduction legislation and policies;
- lack of knowledge and therefore enforcement of waste related legislation; and
- lack of education of the general public.

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

2.2.1 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 Pacific 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.

2.2.2 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 problem. Government authorities should be seen to lead good waste management by example. This education should 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.

With increased public awareness, pressure can be applied to importers by the public, by using their purchasing power to avoid the purchase of high waste, or non-biodegradable products.

There are many sources of information which can be used for educational material namely posters, comic books, videos and internet sites. These can be obtained from SPREP.

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 set-up of recovery and recycling systems, markets for recyclables, and to identify problems within existing Waste Management (WM) practices. Where appropriate, the local municipal authority can then take a facilitative / regulatory role.

3. Support source separation, recovery, and trading networks

Apart from informal source separation, recovery and local recycling / reuse, this is often not appropriate for the majority of SIDS, as the quantities of waste is not large enough to support viable trading networks. In addition, the isolation of the islands makes delivery of most recovered materials to outside markets uneconomic. However, there is a strong case for separation of items such as paper, cardboard, glass bottles, aluminium cans and steel for reuse or recycling. Separation of the items are either carried out at ‘curb’ collection where items such as paper/cardboard, glass and metals are put in small separate containers for collection. Where there is no “curb” side collection, recoverable items may be put in to large collection containers located at convenient areas for individuals to place items. This may be at a school or shopping centre.

Materials Recycling Collection Container (Credit Warmer Bulletin)

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

This is already in place to a small extent. An example of this is the collection, crushing and sale of aluminium cans, which is done in many of the different SIDS including Tuvalu and the Cook Islands. This type of venture has often met problems with can crushers becoming broken, and not being able to be fixed, or other impurities, such as steel being mixed with the aluminium, resulting in the reduction of value. Another small enterprise example is the operation of a privately operated waste collection contractor in Rarotonga. Given the small populations however, and isolation of most Islands, opportunities for such enterprises would be limited.

5. *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 encouraged along with some general guidelines to minimise health and safety problems relating to waste picking.

6. Reduce waste via legislation and economic instruments

After consulting with major stakeholders, advocate, where advisable, selective waste reduction legislation on packaging reduction, product redesign, and coding of plastics.

The majority of non-biodegradable waste in SIDS waste streams is derived from the importing of packaged goods. Packaging could be reduced through selective waste reduction legislation, however, it is argued that the Pacific Island markets are too small to impose special packaging requirements on distant exporters. 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.

7. Export re-cyclables

For SIDS, export of re-cyclables is really only possible for materials that have sufficient value, such as crushed aluminium cans. A number of SIDS export used tires to Fiji for re-treading.

8. 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.

Reuse of items such as glass bottles, and containers for storing kaleke, other foods, and bottling coconut oil (sinu) is already common in Tuvalu for example. (AusAID 1998).

9. 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.

2.3 Collection and Transfer

Collection and transfer of waste on the smallest islands and some of the larger islands is generally up to the public. In these cases, it is the public's responsibility to deliver waste to the designated landfill. Often, waste is haphazardly landfilled, dumped in the mangroves, or placed on the reef to be taken out to sea on the high tide.

In the more populated islands, collection is usually the responsibility of the municipality within the urban areas. Waste is either left at the front gate, or deposited at central transfer points, where it is then collected by the municipality. In Kiribati, waste is swept into piles on the street, and collected by a small team of council workers using a shovel, broom, and sheet, to throw the waste onto a trailer. There are also some instances where waste collection has been contracted to private enterprises. In some larger islands such as Pohnpei in the Federated States of Micronesia, rural inhabitants are expected to deliver their own waste to the landfill, or burn as much of it as possible.

Typically, in SIDS, a large percentage of waste collection equipment does not operate properly, or is out of service completely due to lack of maintenance, spare parts, or necessary expertise. Any of the different collection technologies suggested will only be sound practice, if the necessary preventative maintenance, is carried out. Such maintenance includes replacement of worn parts, lubrication, top up of oil and brake fluid, cleaning, and washing.

2.3.1 Environmentally Sound Technology for Collection and Transfer of Waste

The collection vehicle used must be appropriate to the terrain, the type and density of waste generation points, the roads and ways it must travel, the kinds of materials it will be used to collect, the strength, stature, and capability of the working crew, and the point and manner of discharge of its load. 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.

2.3.2 Principles for Selection of Collection Vehicles

The following principles outlined below represent sound practice, with reference to Pacific 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 parts are available.* This is critical in SIDS of the Pacific 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 Pacific 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. E.g. 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.

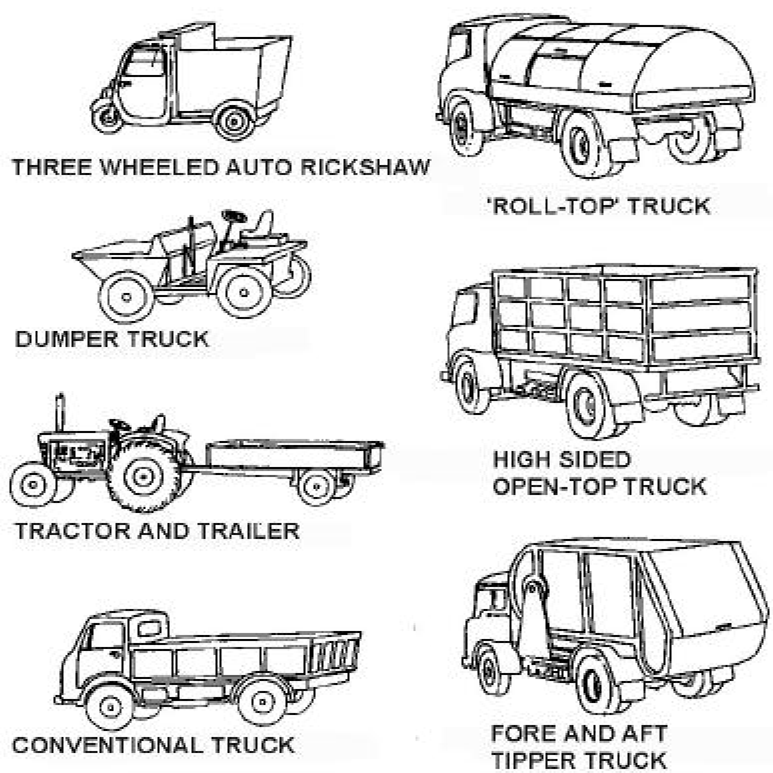
- *Consider compactor trucks in industrialised urban areas where roads are paved, and waste is not too dense or wet.* Compaction is often seen as more efficient, however, due to the typically high organic content and therefore high density of waste collected in SIDS, compaction does not significantly 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.*

Table 1: Different collection vehicles available.

Type of Collection Vehicle	Extent/potential use in SIDS	Comment
Small dumper trucks	May be used	– based on modified jeep or 4WD, – smaller capacity
Fore-and-aft tipper/compaction truck	Known to be used in Fiji	– enables mechanical loading from transfer bins, and compaction of waste. Not suitable in most SIDS
Tractor and Trailer	Commonly used on SIDS	– easily used for other work apart from waste collection
Conventional Truck	Commonly used on SIDS	– 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,	Is used in some SIDs	– suitable for large loads. Could be used in combination with small collectors
Human drawn handcart, Animal drawn cart, and human pedal cart.	Not likely to be used	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 use these.

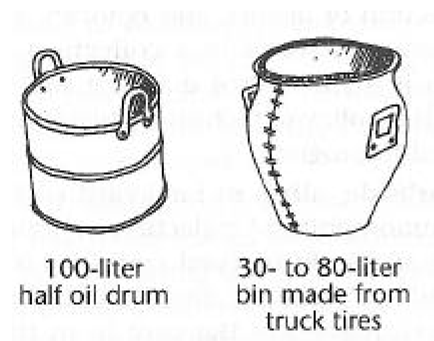


A large variety of vehicles can be chosen from for collection. (Credit: UNCHS (Habitat)).

2.3.3 Sound Principles for Selection of Set-out Containers

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.
- Choose containers which are easy to identify, either due to shape, colour or special markings.



Set out Containers can be made from a wide variety of materials (Credit: United Nations Centre for Human Settlements (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. Easy to open and empty, dog proof, and of sufficient size to hold the expected waste quantities produced, but not larger than needed as this will promote increased waste disposal rather than minimisation.
- 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, for example, 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.

2.3.4 Sound Practice for Route Design and Operation

Collection of waste or recyclables tends to be organised into areas or routes. A service area is the region or area which falls under the responsibility of a local government, public authority, or private company. The method, frequency, and timing of waste collection can vary significantly, depending on each situation. The most efficient system should be sought to meet the specific needs and conditions that exist in each island, and within different areas of each island. An efficient system should aim to cover the necessary service area while using the least amount of capital, labour and time.

Sound principles in collection route design and operation include:

- ***Timing of collection*** should coincide with times when other traffic on the road is least, to avoid unnecessary delays in collection and for other road users.
- ***Sizing of collectors*** appropriately so that the time spent travelling between the source and the disposal site is minimised.
- ***Speed of vehicle:*** Where households are far apart (in rural areas), a faster vehicle will be more efficient. Where households are close and compact (in urban areas), a slower larger capacity vehicle may be better
- ***Collection frequency*** should be set to match the expected volume of waste produced, size of containers, and local preferences, and should keep in mind the health risks that would arise from infrequent collection.
- ***Kerbside collection*** of waste from containers set on the kerb or roadside is common.
- ***Central location:*** In some situations requiring households to take rubbish to a central collection point (such as the end of a street) will increase the efficiency of collection. It may also result in the reduction of waste quantities, as households become more aware of the amount they need to cart to the central collection point.
- ***Competitions to encourage tidiness:*** In many areas of Indonesia, the responsibility of waste collection and street sweeping is given to each village or kampung. All waste from the village is taken by hand or cart to a central point where it can be collected by the municipal authorities. Competitions are then held between different kampung to encourage tidiness. A system like this could easily operate within SIDS with divisions between villages, or between streets, whichever is appropriate.
- ***Communal collection points***, where individuals bring their waste directly to a central point (usually a container) is often used in developing countries. This method of collection requires regular servicing by municipal authorities to ensure the central collection site is emptied, cleaned to minimise odours, vectors, animals, and flies. There is also more potential for hazardous wastes to be left at the central site without knowing who left them. A series of recycling containers could be used at these sites to encourage separation of particular wastes such as glass, paper, aluminium, or organics for reuse. (See also Transfer Below)

- ***Special Collection runs*** for bulky, items such as old appliances, and electronics, furniture, or construction materials.

- ***Rules for collection of rubbish should be made clear*** to all residents and businesses before the new collection system is introduced. These rules should include the times of collection, frequency, and list of what wastes can be disposed of, and what materials should be kept aside for recycling or reuse.

2.3.5 Sound Practice for Transfer of Waste

Transfer stations are centralised facilities where waste is unloaded from smaller collection vehicles near to waste sources, and reloaded into larger vehicles (including sea barges), for transport to the final disposal or processing site.

Transfer stations represent sound technology when:

- there is considerable distance between the main waste source, and the final waste disposal site;

- they can double as a sorting, and separation point for recyclable, reusable, hazardous, and compostable materials;

- they can accommodate the full range of collection vehicles already in use or planned, including private trailers;

- sized to allow waste to be accumulated if necessary prior to long haul transport;

- operators respect and abide by agreements made with neighbours; and

- locally made equipment, local designs, and local expertise are used where possible.

Transfer stations require additional capital costs to set up, additional handling of waste, and need to have sufficient supervision and management to ensure the sites operate efficiently, and do not degenerate into unregulated dumps.

Transfer station should be sited appropriately taking into account the location of the final waste destination, source of the waste, and potential impacts on neighbouring properties, remembering that transfer stations can produce significant noise, odour, air emissions, and traffic. Where the waste disposal site is far from a village, city or town a transfer station is often the best way to ensure users have easy access to dispose of waste, and that the waste can be efficiently transported.

Table 2: Different transfer technologies.

Type of Transfer Technologies	Potential use in SIDS	Comments
Large truck and trailer units	Not likely	– Likely to be oversized for most SIDS applications. – Single high sided trucks may be most appropriate.
Sea Barge	Good potential	– Where waste is to be disposed of on another island. – Presents possible problems with loosing waste to sea during the voyage, and when transferring on and off the barge.
Open tipping floor	Most suited to SIDS	– More efficient for small volumes of waste. – Allows waste sorting, materials recovery, and transfer of materials onto different vehicles for different destinations.
Open Pit	May be suited in some cases	– Similar to tipping floor but is not ideal for sorting and recovery of materials. – Has higher capital and operating costs, and – Is more vulnerable to breakdown.
Direct dumping	Not recommended in SIDS	– Collection trucks unload through hoppers directly into larger transfer trucks. – Does not permit sorting and recovery of materials. – Requires high equipment maintenance, repair, and replacement.

2.3.6 Sound Practice in Keeping Streets Clean

The majority of urban and semi-urban areas in the world have some form of system in place for keeping streets clean. These include litter bins, mechanical sweepers, and manual sweepers. The intensity of such cleaning activities, varies depending on the level of use, and quantity of dust and other litter that is generated in a particular area.

- ***Provide litter bins*** in public areas such as central shopping areas, beaches, and outside small food shops, and encourage their use through education, and enforcement if necessary.

- ***Clearly define responsibility for emptying litter bins*** so that they do not spill onto the street.

- ***Planning of sweeping routes*** needs to be done while taking account of the length of route that can be completed in one day, the frequency of sweeping, and where sweepings will be deposited.

- ***Manual sweeping systems*** are the standard in sound practice for most countries.

  For a manual system, sweepers collect their own sweepings in a small cart and meet a collection vehicle at a centralised point.

  Alternatively the wastes could be placed in paper bag or litter basket or lined up in piles on the kerb side to be collected by a separate truck.

The status of waste workers can be improved with uniforms and good equipment. (Credit: Chris Furedy).

- ***Mechanical sweeping systems*** include four and three-wheeled sweepers, and vacuum trucks.
- Mechanical sweepers should only be used where these can be matched appropriately with the service areas.
- In the majority of SIDS, it is likely that manual sweeping will be preferred over mechanical sweeping as the mechanical sweepers require high capital, operation, and maintenance expenditure.
- Optimise manual pickup efficiency and health and safety, by providing sweepers with better uniforms, brooms, collector bins, and gloves.
- Keeping streets clean should be the responsibility of the Municipality. However, there may be a case in SIDS for a more decentralised system, where the responsibility is placed on individual streets, or villages leaders to delegate this work appropriately.

There are many possible variations in background conditions even within SIDS, which affect the selection and design of a sound solid waste collection and transfer system. These include terrain, settlement patterns, cultural preference and waste composition. Designers of waste collection systems need to take these into account and will often need to combine different technologies as they seek to account for the background conditions of the particular location.

2.4 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 land filled, 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.

Anaerobic processes, on the other hand, occur in the absence of oxygen. The by-products include non-oxygenated compounds except for phosphates and water – such as methane, ammonia and hydrogen sulphide. These by-products are not plant food and instead serve as a system contaminant.

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 Pacific region SIDS.

2.4.1 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.

2.4.2 Sound Technologies for Composting

The following tables provide a range of technologies available for composting, from small backyard to large scale regional systems. In evaluating composting as a technology, the character and type of waste stream to be composted needs to be determined. In this respect, the following points should be noted and investigated further if relevant:

- Waste may need shredding or chipping to reduce size and speed up composting

- 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

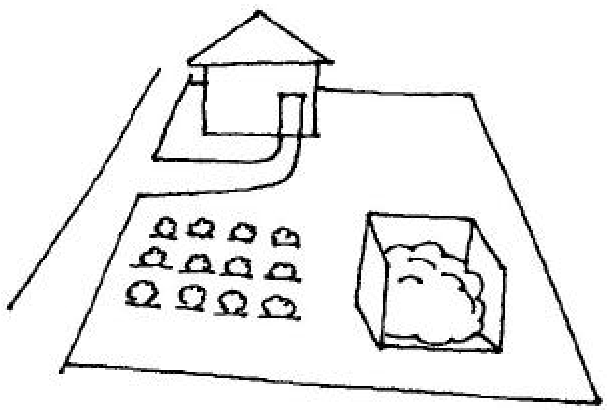
- The extent of animal feeding using kitchen waste should be accounted for. In many SIDS, pigs are kept to consume kitchen wastes, and provide meat, resulting in reduced quantities of waste being available for composting. Feeding waste to animals achieves a higher level of nutrient utilisation than composting,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

- Wastewater sludge, and human faecal matter can be composted, however, they are high in nitrogen and moisture. They 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 is generally composted in farm applications, and is an important aspect of sustainable farming. Such wastes can easily be incorporated into community or larger scale composting systems.

Composting system:

Backyard Composting on Household Scale



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, 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

Extent of Use:
- only on an informal basis in a few areas
- encouraged in some SIDS but not common in others

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

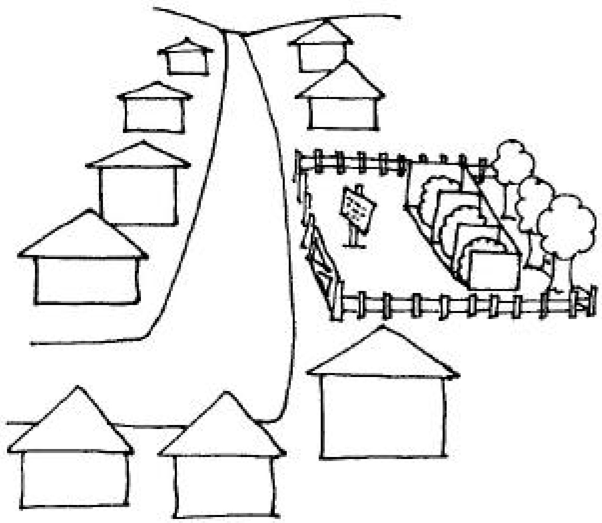
Relative Cost:
- very low
- costs for bins, and for training

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, where the waste stream contains primarily vegetable matter rather than animal matter
- Yes, because they are appropriate technology, and can be developed locally

Composting system:

Neighbourhood, Block, or Business Scale Composting



Technology Description:

Decentralised composting where quantities of less than 5 tons per day of waste are collected to a central composting point within a neighbourhood, block, or number of businesses.

The site would include a series of concrete or timber bins which could be alternately filled, composted, and emptied. Support from the Municipality with technical advice, turning of compost, and emptying would likely be necessary.

The site would need good signs and fencing instructing of acceptable wastes, current dumping area, and to keep unwanted animals out.

This Technology is a Sound approach when:

- within close proximity of the waste source,
- sited beside community gardens, or park reserve,
- has approval from all neighbours,
- the waste stream contains primarily vegetable matter rather than animal matter,
- clearly designated with signs,
- have adequate fencing, and
- good soil for leachate adsorption.

Extent of Use: Encouraged on some SIDS but not generally common

Operation and Maintenance:

- on this scale of operation, collection would typically be up to individual households, with responsibility for co-ordinating, cleaning and maintaining order given to a neighbourhood supervisor, with backup from the municipality to provide technical advice, support for removal of undesired items, or turning of the piles.

Advantages:

- minimal collection, transfer and final marketing costs
- low cost
- encourages public involvement
- enables more control from municipality

Disadvantages/constraints:

- can cause significant problems with high vermin populations, animals, insects, and odours from site
- relies on public participation
- potential for other non-compostable waste to be dumped at site

Relative Cost: low

- initial – site set up, and for training
- ongoing – site supervisor, municipality support

Cultural Acceptability:

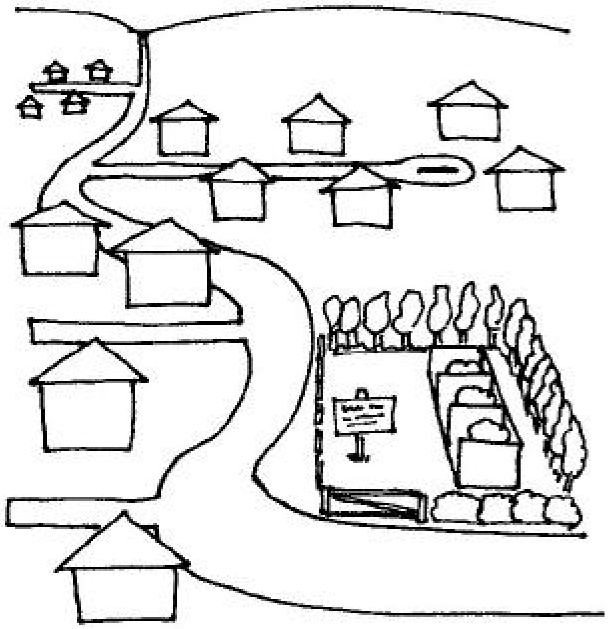
- may be land use issues for site chosen

Suitability

- Yes, where houses don't have sufficient yard space for backyard systems, and where there is a suitable local community park or garden.
- Yes, where organic wastes are not otherwise fed to animals.
- Yes, because they are appropriate technology, and can be developed locally.

Composting system:

Village and Community Scale Composting



Technology Description:

Quantities of 2-50 tons per day of waste are collected from the kerbside to a central composting point within a village, community or town.

The site would include a series of concrete or timber bins which could be alternately filled, composted, and emptied. Alternatively, windrows may be used. This scale of composting must come under the jurisdiction of the Community Authority but could be privately operated. The site would be similar to the neighbourhood system, but on a larger scale, with more area to accommodate more 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 animals out.

This Technology is a Sound approach when setup within close proximity of the waste source, and when it has approval from all neighbours

Extent of Use: encouraged, and promoted in Tarawa, Kiribati.

Operation and Maintenance:

- on this scale of operation, collection could be by individual households, or kerbside collection, or a combination of these two, with responsibility for co-ordinating, compost processing, marketing, cleaning and maintaining order with the Community Authority.
- operation and maintenance increased with increased collection and processing equipment needed.

Advantages:

- reasonably compact with low haulage costs
- medium cost
- good control from Community Authority
- low input required from individual households apart from separation of compostable wastes

Disadvantages/constraints:

- can cause problems with vectors, and odours from site
- requires reasonably large area

Relative Cost: medium

- initial – site set up, and for Training
- ongoing – collection and site operators, and machinery

Cultural Acceptability:

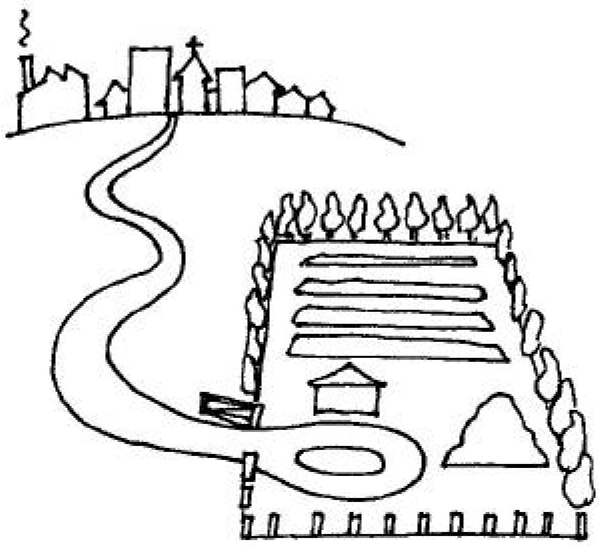
- may be land use issues for site chosen

Suitability

- Yes, where there is insufficient space for a smaller scale system.
- Yes, where large portions of organic wastes are not otherwise fed to animals.
- Yes, where appropriate collection, and processing technology, can be developed locally.
- Yes, where a market is available for the compost.

Composting system:

Centralised Composting on municipal Scale



Technology Description:

Quantities of 10-200 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.

Must come under the jurisdiction of the municipality, but could be privately operated. The site would be similar to the community system, but on a larger scale, with more area to accommodate more vehicles, compost turning, processing, screening, and storage.

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 to ensure quality
- a formal system of using and marketing the Compost product is adopted

Extent of Use: no formal sites exist

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
- more suitable locations outside of town or city
- economies of scale
- low input required from individual households apart from separation of compostable wastes

Disadvantages/constraints:

- higher haulage costs,
- requires large area of land
- can cause problems with noise, vectors, and odours from large site

Relative Cost: medium - high

- initial – site set up, vehicles, and for training
- ongoing – high operating and machinery maintenance costs

Cultural Acceptability:

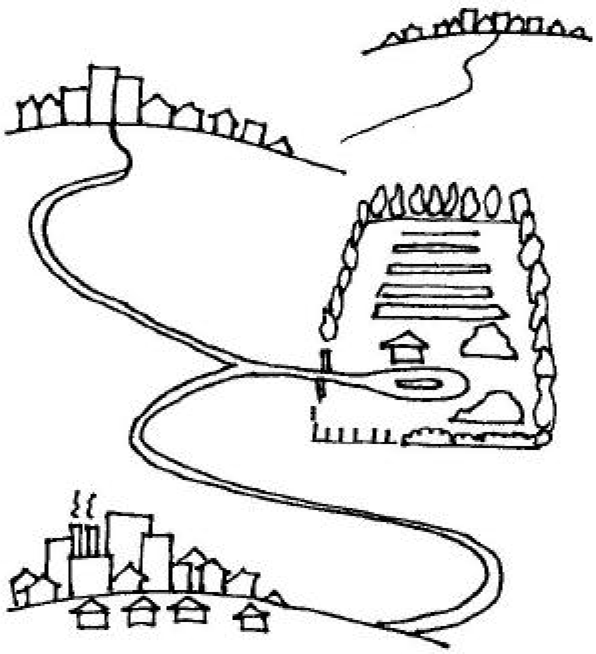
- may be land use issues for site chosen

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.

Composting system:

Centralised Composting on National Scale



Technology Description:

Quantities of 50-1000 tons per day.
Where waste is collected from a number of source cities, towns, or islands, within a region and composted at one large site. This requires significant transportation costs.

Technology as for the centralised composting systems, but on a larger scale, with more area to accommodate vehicles, compost turning, processing, screening, and storage.

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.
- siting needs to take into account equity effects of siting a compost plant for many municipalities, or islands within just one municipality, or island, with remediation and compensation where necessary.
- agreements regarding siting, financing, operations, maintenance, environmental compliance, billing for services, delivery and quality of waste, compost quality use, and marketing need to be made between different parties.
- technical and environmental assessments, engineering design, and formal evaluation of all issues involving all stakeholders is completed.

Extent of Use: not known to be used

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 on a regional basis
- allows most suitable site to be chosen
- provides solution for islands where land area is available

Disadvantages/constraints:

- higher haulage costs in collection and re-distribution
- requires large area of land
- potential for conflicts between islands or municipalities within region

Relative Cost: High

- initial – site set up, vehicles, and for training
- ongoing – high operating, marketing and machinery maintenance costs

Cultural Acceptability

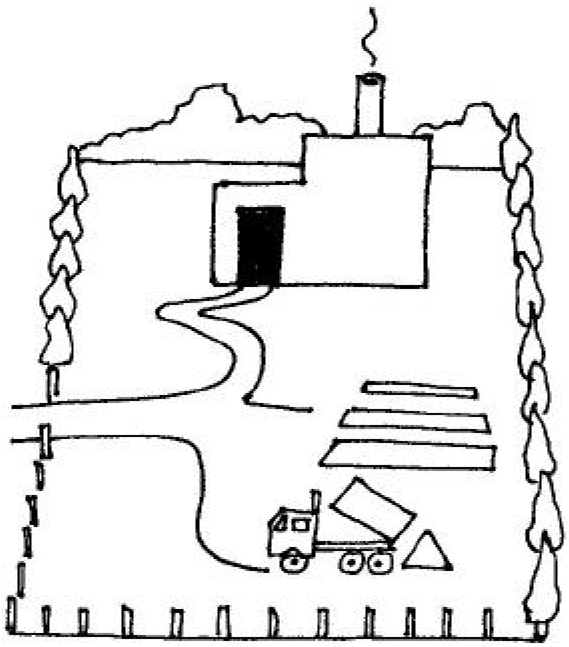
- may be land use issues for site chosen

Suitability

- Only where there is insufficient space or limitations 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.

Composting system:

Composting at an Integrated Waste Management Facility



Technology Description:

Quantities vary depending on source size.

Semi-informal composting, where compostable materials are piled up to one side at the landfill for "natural composting" without turning or sorting.

Siting is rolled into the landfill or incinerator siting process.

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:

- alternative sites are limited,
- financial or organisational structures are lacking,
- other composting technologies are not sound.

Extent of Use: used on an informal basis in a number of SIDS

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
- same equipment can be used

Disadvantages/constraints:

- poorer quality compost produced
- less control on environmental effects of process

Relative Cost: medium

- initial – medium site set up, and for training
- ongoing – medium operating and machinery maintenance costs

Cultural Acceptability

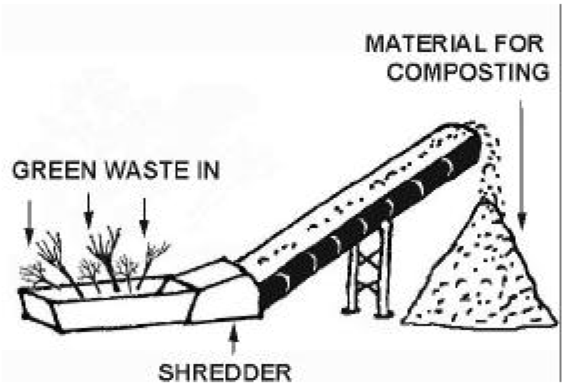
- may be land use issues for site chosen

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.

Composting Technology:

Pre-processing Equipment



Technology Description:

Done to separate non-compostable waste, 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, however, is not generally considered sound practice if relied heavily on in a composting system.

Extent of Use: none known to be used in SIDS

Operation and Maintenance:
- operation and maintenance cost is high
- maintenance needed

Advantages:
- allows for optimum composting to be achieved
- produces well blended, small size compost product

Disadvantages/constraints:
- costly
- high maintenance, and vulnerable to breakdown (especially if banana leaves are used)

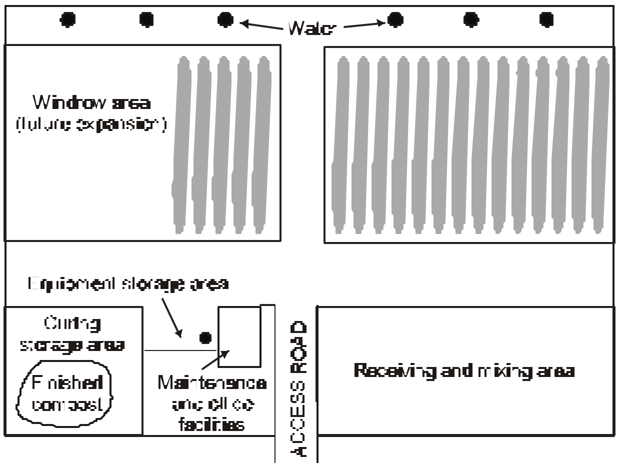
Relative Cost: High
- high initial – capital costs for machinery
- ongoing – high operating and machinery maintenance costs
- cost depending on size AU$50,000

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 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, or by static aeration introducing air via a network of perforated pipes within the compost pile.

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 in developed countries with mechanical aeration by turning rather than static aeration, but not within SIDS

Operation and Maintenance:

- operation and maintenance needed for aeration machinery.
- fencing needed to keep animals away.

Advantages:

- mechanical turning has lower capital costs, and machinery is not too specialised
- static aeration requires less land area

Disadvantages/constraints:

- mechanical turning requires higher land use
- 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

Table 3: 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.
Traditional Root Crop (Babai) composting from Tuvalu	High potential	– Traditional use of dried or green leaves as compost. – Composted leaves are then used to grow root crops and are also a method to remove green waste. – Leaves are buried in the mud surrounding the root crop as additional food for the plant. – This process happens several times until plants are ready for harvest.
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. – 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	May be suitable	– 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 likely	– Expensive to build and operate. – Higher technology, and therefore more likely to break down.
Tower systems.	Not likely	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. – Significant potential for health and safety problems, due to glass, or contaminants within the waste.

Vermiculture or vermicomposting or worm farming	May be suitable	– 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.

2.4.3 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;
- subsidising the price of compost for sale;
- removing or modifying subsidies on chemical fertilisers;
- giving high profile coverage to business or public applications where the benefits of composting has been proven; and
- encouraging 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.

2.4.4 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.

Leachate contains high Biological Oxygen Demand (BOD), and some phenols, and surface runoff should be allowed to soak into the underlying soil, or captured and treated through a sand filter before being discharged to ground, or water.

2.4.5 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 exist.

In SIDS, composting has not been a way of life for residents, however, with increasing pressures on landfill space, available cover materials, 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 Pacific Region.

2.5 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 (World Health Organisation (WHO) Fact sheet 1999).

2.5.1 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

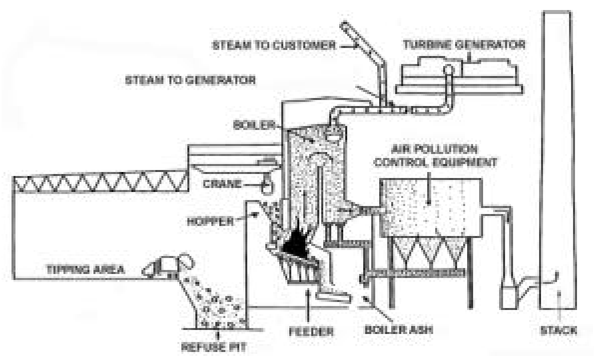
3. Fluidised Bed Incinerators

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. 100-3000 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 necessary operational and environmental controls can be set and maintained.

Extent of Use: none used in Pacific 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:

- very high

Cultural Acceptability

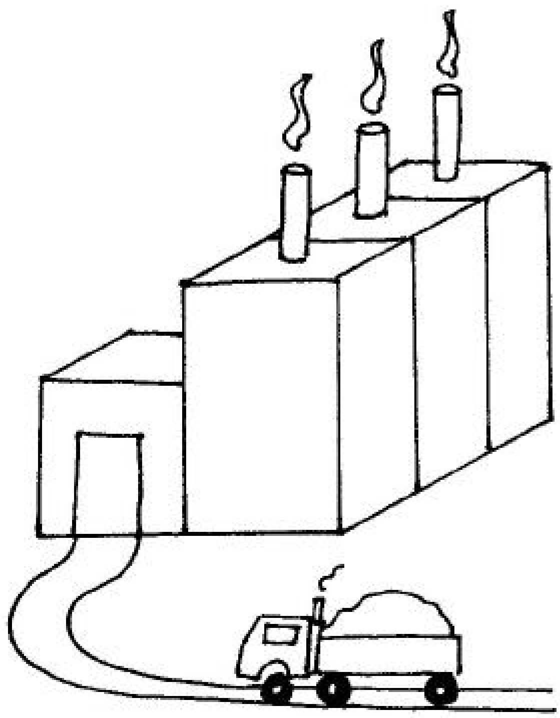
- air discharges likely to be unacceptable

Suitability:

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

Incineration Technology:

Modular Incinerators



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.

Operation uses 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 necessary operational and environmental controls can be set and maintained.

Extent of Use: none used in Pacific SIDS but may suit smaller communities, or for commercial and industrial applications.

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

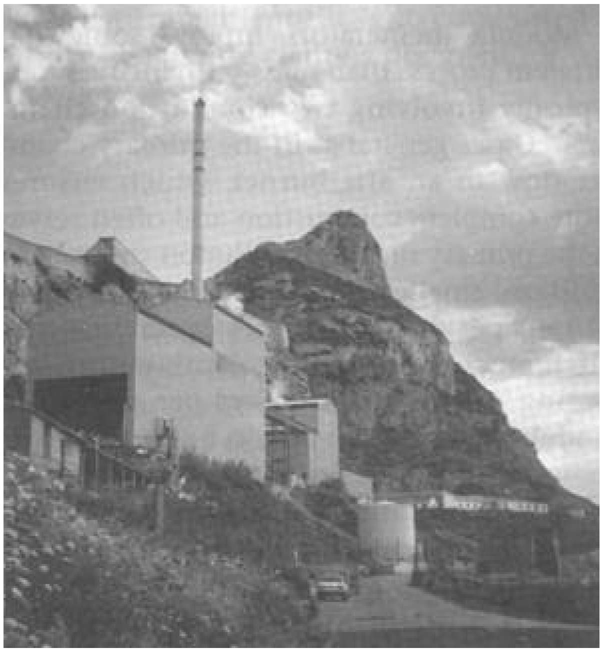
Relative Cost:
- very high but less than other MSW incinerator options

Cultural Acceptability
- air discharges likely to be unacceptable

Suitability:
- Only where landfilling area is scarce.
- 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 at 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 necessary operational and environmental controls can be set and maintained.

Extent of Use: used in Japan and some European countries but none in Pacific 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
- more difficult to operate

Relative Cost:

- very high, savings over other systems inconclusive
- likely to have lower maintenance costs than other incineration options, but still very high

Cultural Acceptability

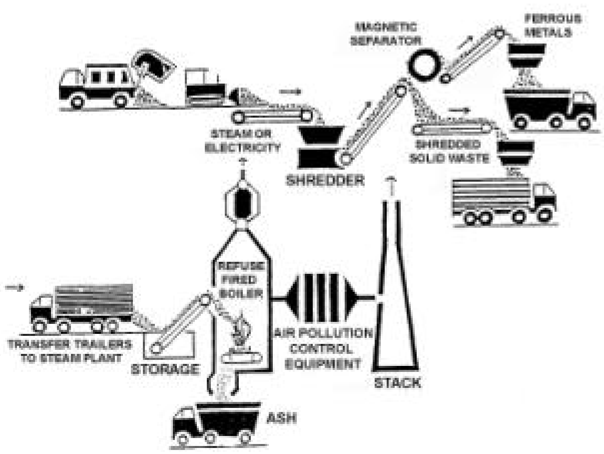
- air discharges likely to be unacceptable

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 necessary operational and environmental controls can be set and maintained.

Extent of Use: not used in 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 due to air pollution.

Advantages: (over other incineration technology)
- more compatible with high recovery/re-cycling 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:
- very high, due to higher level of pre-processing
- likely to have higher pre-processing maintenance costs

Cultural Acceptability
- air discharges likely to be unacceptable

Suitability:
- Only where landfilling area is scarce, and
- Where a high level of expertise, for operation and maintenance is available.

2.5.2 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 through 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.

2.5.3 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.

2.6 Landfills and Other Methods of Disposal on Land

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

Landfills 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.

An alternative to the traditional "anaerobic" landfilling is the Fukuoka method which is an "Aerobic" landfill technology promoted by UNCHS (Habitat). This technology is described further in the technology summaries that follow.

2.6.1 Open Dumps

Open dumps are very common in Pacific 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 land area, cover material, and financial constraints. 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 sound technology.

A study by Asian Development Bank (ADB) regarding "Sanitation and Public Health" (1996), in Kiribati, described current waste disposal practice. It was reported in the study that only one of the sites used by the council for MSW disposal was satisfactory. This site used sand as cover material. Apart from this site, MSW was often dumped at designated sites along the beaches at high tide mark. As a result, significant portions of this waste gets washed out to sea.

It was noted in this study however, that these dump sites had different characteristics to dumps found in other industrialised countries. The green wastes dominate up to 60% of the total volume, and typical landfill nuisances, such as wind blown litter, smell, flies, rats, and birds were not present. It was even suggested that the leachate strength is likely to be significantly less from these sites.

During an inspection of open dump sites in Funafuti, Tuvalu (SPREP 1998), an unusually low level of odour was also observed, despite the lack of cover material, and hot climate. A possible reason for this is that most putrescible material is fed to pigs or other animals.

It can be concluded from the above observations that landfill cover may not be necessary where the quantity of putrescible waste is low It may also be true that the impacts on groundwater, and surrounding neighbours due to landfilling are less than in developed countries.

However, it is clear from the experience in Kiribati, and most other SIDS, that waste disposal could be more organised, with significant improvements made by minimising waste disposal where the sea can wash waste along beaches. As a result of the ADB study, objectives were set for reducing the final waste quantity by up to 50% using composting and recycling, and ensuring all disposal sites are approved as "secure", by the Government.

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.

2.6.2 Land Reclamation Using Solid Waste

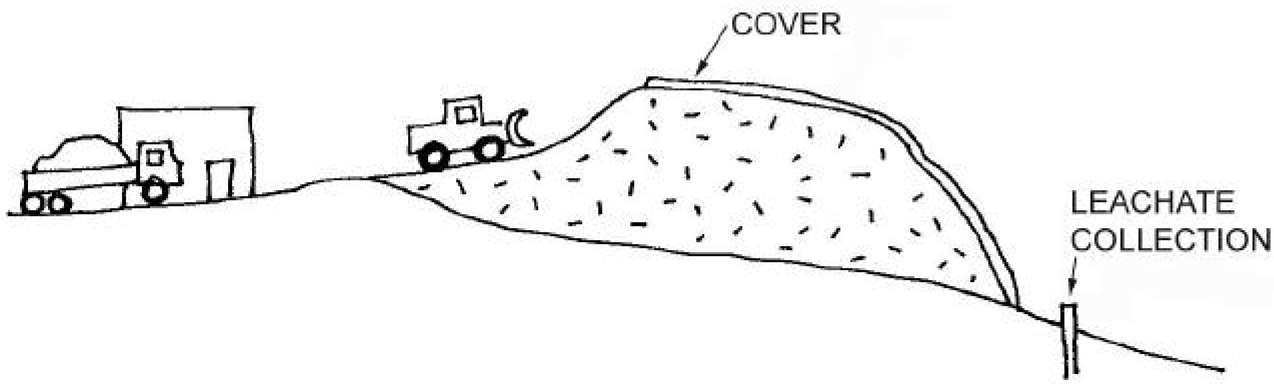
A number of Pacific Region atolls are using solid waste as material for land reclamation projects. This has been observed in Kiribati, (ADB 1996), the Marshall Islands (UNCHS Habitat 1994), among others. Generally, the use of waste for land reclamation has been done in a poorly managed way, resulting (in some case) in significant portions of the waste being washed away by the sea. According to Habitat (1994), "In an urban atoll situation, where land is an extremely scarce resource, the reclamation of land using solid waste is generally an accepted strategy if managed properly".

Principles for sound land reclamation using solid waste include:

- ***Shelter:*** Constructing the reclamation where it is sheltered from the force of ocean storms.
- Provide adequate ***protection*** embankments between the sea or tidal area and the area to be filled to retain the waste.
- ***Restrict entry onto site.***
- ***Remove all hazardous waste prior to disposal.***
- Provide ***final cover to waste*** using sand, or dredging material from the shipping channel.
- Provide a ***vegetation cover*** as soon as possible after the fill is completed.

2.6.3 Landfill Technology Summaries

Landfill Technology: **Controlled Dump**



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 and becoming more common

Operation and Maintenance:
- requires a dedicated operator to ensure the management procedures above are carried out

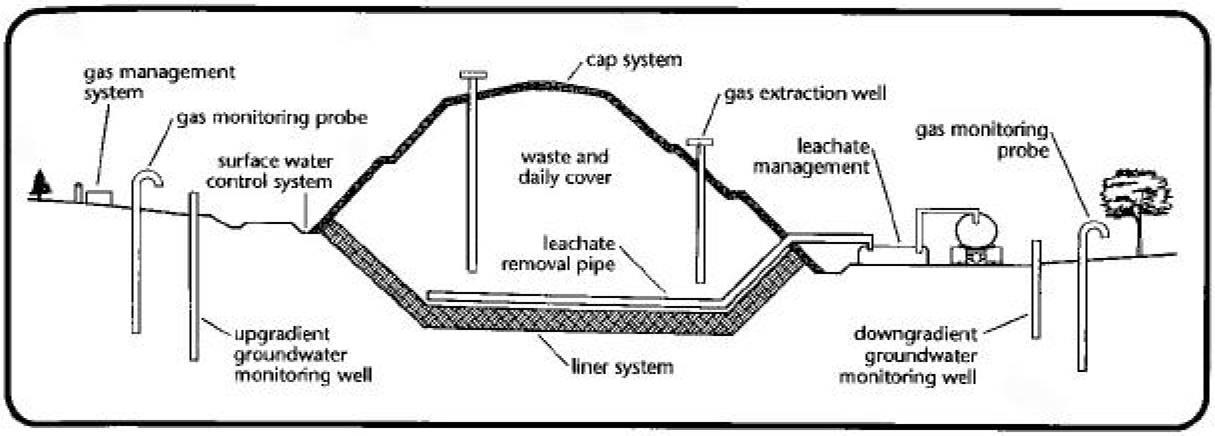
Advantages: (over other landfill options)	Disadvantages/constraints:
• less risk of environmental contamination • permits long term planning • better rainfall runoff • extended lifetime • controlled access and use • good information • materials recovery by waste pickers allowable	• may be less accessible • 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 sanitary landfill 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:

- none believed to be operating in Pacific SIDS, but likely to become more common

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

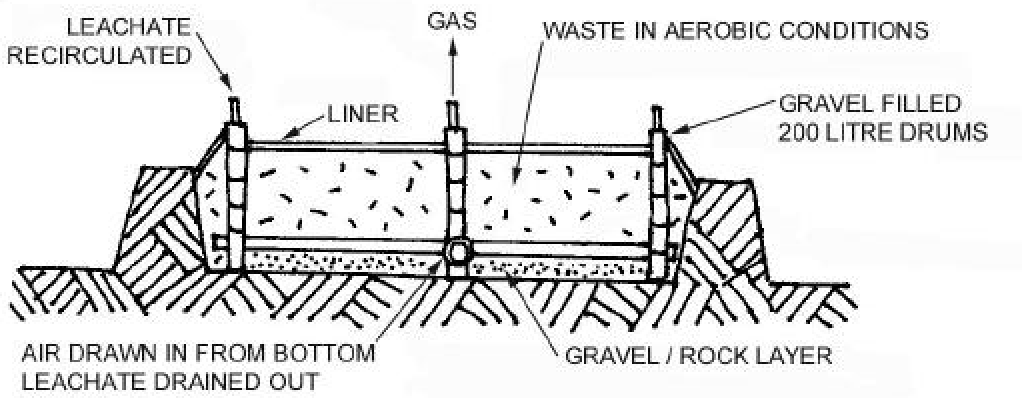
Relative Cost:

- 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.

Landfill Technology: **(Semi-Aerobic Technology; e.g. Fukuoka Method)**



Technology Description:

The Fukuoka Method exploits air convection due to temperature differences to draw air through the waste. It is constructed simply by building up an earth embankment around a site to create a shallow, enclosed disposal area. A perforated pipe network is then laid centrally along the site and embedded in coarse gravel or rock for protection during filling, and to aid air circulation and leachate drainage.

At the end of every pipe branch is erected a perforated standpipe to allow air intake to the landfill, and leachate re-circulation. The vertical standpipes are protected by standing 200 litre oil drums over the standpipes and backfilling with rock.

Waste is then spread over the pipe work using a bulldozer for spreading and compaction. Leachate is collected from the drains, retained in a pond and re-circulated.

Extent of Use:

- not used in the Pacific SIDS but widely used and accepted in Japan

Operation and Maintenance:

- requires reasonably high operation and maintenance input

Advantages: (over other landfill options)

- less risk of environmental contamination
- more rapid waste decomposition
- aerobic conditions minimises the production of odours, and nitric acids, improving leachate quality
- site regeneration is more rapid, with final use as recreation and parks
- it is cost effective compared to anaerobic landfills
- reduces production of greenhouse gases
- requires less area
- ensures controlled filling

Disadvantages/constraints:

- requires a medium level of o & m

Relative Cost:

- more expensive than open dumping, due to higher level of initial capital setup costs
- higher operating costs due to compaction, covering, and other landfill management procedures listed above

Suitability:

- Yes, for new sites, this method will take up less space than current hap-hazard disposal sites.

2.6.4 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 or 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 (e.g. 1-2 mm HDPE) are very impermeable but being thin are more susceptible to damage.

  Where natural clay soils are unavailable (e.g. 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 drainage 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 off 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 so 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.

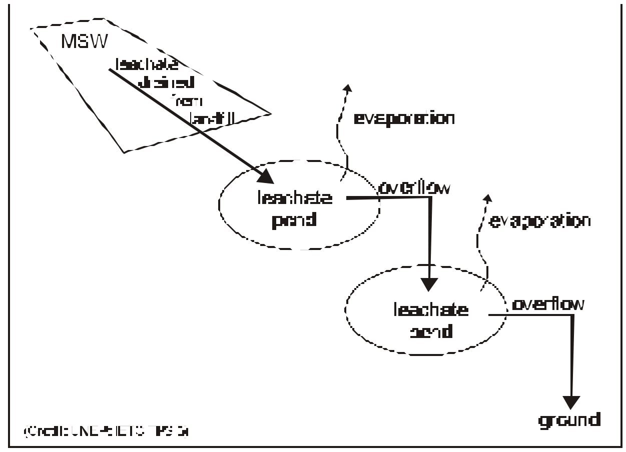
- **Leachate Re-circulation** is not really an option for the "disposal" of leachate, however it is effective at reducing the strength of leachate and so can make subsequent treatment steps easier. In a hot dry climate it may also be effective at reducing the overall volume of leachate requiring treatment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

- **Drying of waste to reduce leachate** is a cheap alternative to help reduce the quantity of leachate where dumps or landfills do not have liners. This is done by partially drying waste at the transfer station prior to placing in the landfill.

- **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 will 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 ponds could be used as detailed right to allow evaporation and natural biological treatment. These ponds need to be sized based on a hydraulic balance of leachate, evaporation, and rainfall.



Cascading Leachate Ponds

Note: Leachate ponds need to be lined to prevent soakage into the ground. 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 uses the 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 requires 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 ongoing 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.

Material has in some cases such as Funafuti in Tuvalu, been dredged from lagoons (AusAID 1998) for use as fill material. The use of dredged harbour and lagoon material, as landfill cover may be sound practice where this does not adversely impact on the lagoon or harbour marine environment.

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 humanly safe and 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.

2.7 Special Wastes

2.7.1 Tires

Tires require high-energy input to be able to recover any of the materials for reuse, and this process is hazardous. In addition, tires do not sit well in landfills, where they tend to “float” to the surface, making it difficult to maintain the soil cover above the waste.

The following are sound practices for management of tires:

- ***Reuse*** including: re-treading, shredding and grinding for use in road paving materials, cutting them up for use as padding in playgrounds, buffers, rubbish containers, door mats, growing potatoes in tire stacks, or swans…. It should be noted that tire materials may be carcinogenic, and therefore workers should avoid dust and buffings when working with tires.

- ***Thermal destruction in Cement Kilns with energy recovery***. Such kilns require adapting to take the tires, however, once this is done, this has been found to be a good method of destroying tires. Fiji has a cement kiln which could be utilised in this way.

- ***Processing in pyrolytic ovens***. This is only sound practice when gas emission controls are used to trap harmful organic vapours. This is generally expensive and needs technical input, and therefore is not likely to be sound in SIDS.

2.7.2 Construction and demolition debris

Demolition wastes largely consist of cement, bricks, asphalt, wood, and other construction materials that are largely inert, apart from some hazardous asbestos, and PCB materials. These wastes can take up a large volume if disposed of with other wastes. However, they are not usually suitable as ordinary fill material.

The following are sound practices for the disposal of construction and demolition wastes:

- Waste reduction through promotion of inventory control, and return allowances for construction materials.
- Selective demolition where specific recoverable, and reusable materials such as timber, windows, and bricks, are removed prior to demolition of the building structure.
- On-site separation using multiple containers for different waste materials
- Crushing, milling, and reuse of secondary stone, and concrete materials for fill, or roading materials.
- Reuse of rock, brick and concrete materials for land reclamation, shore erosion protection, and sea walls.

2.8 Information Sources for the Pacific Region

In the Pacific Region, the main information sources on solid waste are SPREP, SOPAC, UNCHS-Habitat, and in a more general way, UNEP, and WHO.

Contact details for these organisations can be found in section 3.9 under Information sources for the Pacific Region on Hazardous Waste.

3 Hazardous Waste Technologies

3.1 Introduction

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 Pacific SIDS:

(a) medical waste, (from hospitals, clinics, and laboratories);

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

(c) used oils;

(d) batteries;

(e) asbestos;

(f) human excreta, sewage sludge, septage, and slaughterhouse waste; and

(g) industrial waste.

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.

Hazardous wastes are currently often handled poorly. Where incinerators have been installed for medical waste, these often have broken down. In some SIDS, for example South Tarawa, used oil is collected in unlined pits (ADB TA No. 2497).

"Tuvalu, Waste Management Project" (Nov. 1998) by AusAID, reported on options for management of hazardous waste. Some of these options included:

- removal of existing stockpiles of persistent organic pollutants (POPs), such as PCB's, pesticides, solvents, and waste oil to Fiji or Australia;
- collection and storage in concrete containers;

- government to set up agreements with oil companies to take back used oils; and
- increase education to help locals distinguish between general and hazardous wastes.

3.1.1 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. Suitable storage facilities should be:

- secure from unauthorised access;
- weather proof to keep waste dry and prevent leaching to surface or groundwater; and
- 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, and the Waigani Convention (Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Waste and to Control the Trans-boundary Movement and Management of Hazardous Wastes within the South Pacific Region).

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, and lists technologies which may be used to manage these wastes. It also sets out a convention for sound management of hazardous wastes, and in particular the control and minimisation of movement of these wastes between different States, or boundaries.

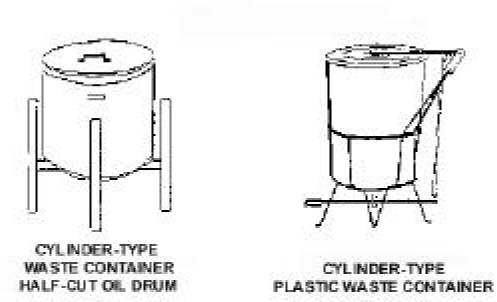
3.2 Medical Waste

Medical waste requires careful handling and disposal because it contains high levels of pathogenic or infectious waste, sharps, and hazardous or toxic substances such as cleaning agents, or discarded medications. In Pacific 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.

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, in Geneva, Switzerland (e-mail: publications@who.ch).

Sound practice for disposal of medical waste should include the following:

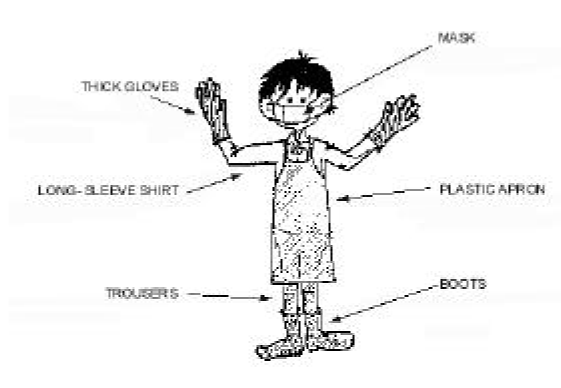
- ***Source separation within the hospital*** to a) separate harmless waste such as paper, cardboard, and food scraps, for reuse and recycling, b) isolate infectious and hazardous wastes using special collection containers, which are colour coded, or clearly different for appropriate disposal.



Source: WHO Webpage

WHO have reported that model medical-waste-management programs in India and elsewhere have shown that segregation and reduction practices can minimise much of the waste that needs to be safely disposed. These programs are successful in reducing the amount of potentially infectious waste, reducing other medical wastes, educating staff, and developing local policies to deal with these issues. The potentially infectious part of the waste is much less than 10 percent (some estimates are 1-3 percent). Therefore, if waste management programs are based on good segregation, they will greatly reduce the waste problem.

- ***Set procedures and equipment for handling and transportation*** to ensure wastes are handled in a sound manner to minimise risk of exposure. e.g. placement of all sharps in secure containers as most appropriate for their final disposal. Provision of appropriate clothing, collection containers, and vehicles for handling the wastes collected.



Source: WHO Website www.int/water_sanitation_health/medwaste

- ***Take back systems***, where vendors or manufacturers take back unused or out of date medication for controlled disposal.

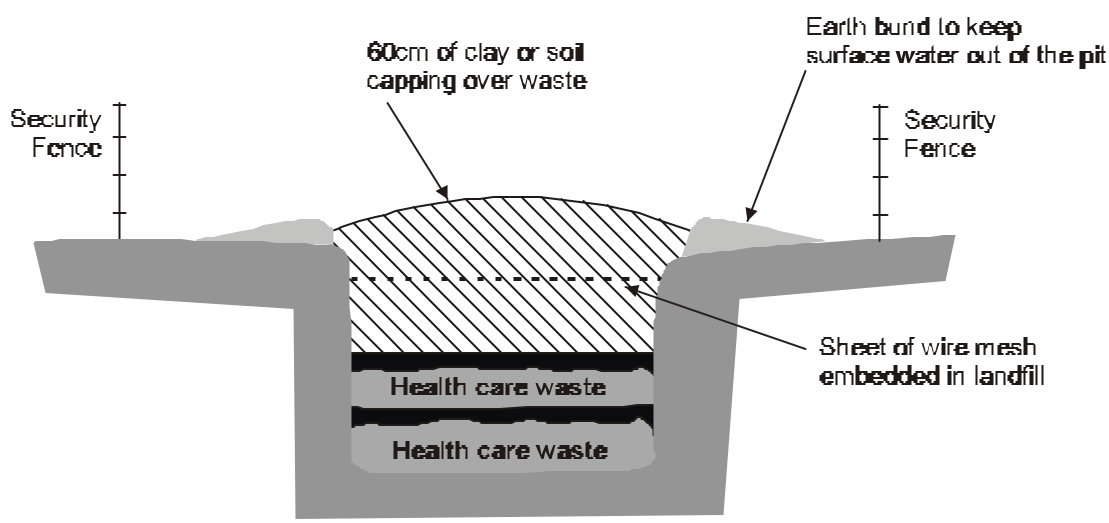
- ***Tight keeping of inventories,*** to avoid wastage.

- ***Piggy back systems***, where nursing homes, doctors offices and clinics can funnel their waste through the main hospital waste system.

- ***Treatment of infectious waste by disinfection***. Disinfection can be done using autoclaving (Steam sterilisation), shredding followed by chemical disinfection or microwaving, and irradiation. Disinfected wastes still require disposal as special wastes and may have their own disadvantages that may preclude their use in many settings

- ***Incineration to dispose of medical waste*** should only be used as an appropriate option for disposal, for a very small part of the medical waste stream. This may include pathogenic wastes (e.g., body parts); certain expired pharmaceutical waste; and some special wastes (such as chemotherapy waste—not usually a problem in developing countries). Anything that is not potentially infectious (over 90 percent of the medical waste) should never be incinerated, especially plastics and metals (mercury). This is because incinerated medical waste can cause significant negative environmental impacts—mainly from extremely toxic dioxins (and furans) produced during combustion of chlorinated plastics (e.g. polyvinyl chloride or PVC). Dioxins are found in the fly ash, bottom ash, and air emissions from the burned plastics (WHO by De Monfort University, UK). Incineration is expensive to set up and requires technical input to operate and maintain. An incinerator needs to be set up and operated by suitable skilled staff. In the case of SIDS the Electricity Corporation or Public Works Department may be the best people to handle this. Ash residues from the incinerator will still contain sharps (needles, and scalpels), and dioxins, and therefore should still be disposed of as special wastes within the landfill.

- ***Proper final disposal.*** Where none of the above practices are possible, due to lack of funding or organisational structure, suitable final disposal is the only way to deal with hospital wastes. For disposal within landfills or dumps, the special waste should be placed in a designated cell or area under close supervision, and covered with a layer of lime, and at least 50 cm of soil. If this is not possible, the special waste should have at least 1 m of normal waste immediately placed over and 2 m to each side of it.



Example of small landfill pit for health care waste

3.3 Household and Agricultural Hazardous Waste

Hazardous wastes make up only a small percentage of the total household waste stream, however the effect of these hazardous wastes in terms of human health and environmental degradation can be far more significant. Hazardous wastes from agricultural practices are similar to household wastes in that they are usually diverse in nature, and most often exist in small quantities. Examples of these wastes include left over oil-based paints, paint thinner, wood preservatives, herbicides, pesticides, cleaners, used motor oil, antifreeze, and batteries.

There are two opposing views as to what is best practice for dealing with such wastes. The first view is to encourage separation of these wastes from other non-hazardous wastes prior to disposal so they can be dealt with as necessary. This is common in industrialised countries where technologies and finance for safe re-cyling, or disposal are available. The second view of what is best practice, is to dispose of household hazardous wastes with other wastes, into normal landfills, where the effect of these wastes is dispersed and diluted throughout the whole landfill. This is seen as preferable to collecting the hazardous wastes together into a single, highly concentrated storage area. In many cases, where there are no alternative methods of dealing with separated hazardous wastes, this may be the most 'sound' approach.

The following are sound practices for management of hazardous household wastes:

- ***Separation of hazardous wastes should be prioritised*** according to the level of damage each type of waste does, when released into the environment through the disposal method that is used, e.g. batteries cause significant problems when incinerated, therefore they should be separated if the waste stream is incinerated.

- ***There should be ample clear public training*** as to the need for separation, and how and where this can be done.

- ***Separation, recycling and collection*** opportunities should be convenient, and frequent.

- ***Hazardous goods should be clearly identified as such at the point of purchase,*** and on labelling, with instructions for special disposal.

- ***An emphasis should be placed on point-of-purchase take-back systems*** for substances which can be collected in this manner such as medicines, used oil, and batteries.

- ***Legislation and policy should be put in place*** to eliminate the import of hazardous goods where non-hazardous alternatives are available.

- ***Personnel handling household hazardous goods, must receive training*** to reduce health and safety risks, and ensure appropriate disposal.

Where resources or options are available for appropriate disposal of specific hazardous wastes, separation of these wastes is appropriate, however, if separation will result in large quantities of poorly controlled, concentrated wastes, it may be better to leave these wastes to be disposed of with normal waste.

3.4 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 Polychlorobiphenyls (PCB's) (SPREP Solid Waste Management).

In Tuvalu, one method of oil disposal reported is to drip it slowly down a u-shaped steel tube. The u shaped base of the tube is heated so that the oil forms a vapour and burns as it enters the u-section. This method of disposal prevents oil contaminating the soil, and ground water, but still results in contamination of the air.

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 Cook Islands and some other SIDS currently export used oil to Fiji, where it is re-refined. 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.

3.5 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:

- **Drainage of acid with subsequent neutralisation**.

- **Export of batteries for re-cycling** (storage area required).

- **Recycling in controlled environments**. Small scale uncontrolled recycling can often be highly polluting and hazardous.

- **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.

Small batteries contain nickel and Lithium. These batteries should also be collected separately from other waste and exported to suitable offshore countries for disposal. Provision of storage necessary to contain these batteries prior to exporting.

3.6 Asbestos

Asbestos (which is a carcinogenic material) should be sealed in a plastic bag, and buried sufficiently deep in the landfill such that it won't be uncovered. Wetting of the asbestos prior to handling will help suppress the harmful fibres and dust. Breathing apparatus and protective clothing should be used when handling asbestos.

3.7 Human excreta, sewage sludge, septage, and slaughterhouse waste

These wastes can contain large levels of pathogens and chemical contaminants that at these concentrations are hazardous to human health and the environment. However, these wastes do contain significant nutrients, food value and biomass which if handled correctly may be beneficial and profitable as fertilisers, compost, animal feed and glue.

The following are sound practices for reducing and handling sewage sludge, septage:

- **Preventing large volumes of sludge** through separation of sewage and stormwater drainage systems.

- **Minimise reliance on centralised sewage system** by installation of onsite treatment, and separation of household washwater for reuse.

- **Land application** requires regular monitoring of the sludge to show that the metal content is very low.

- **Treatment such as drying, liming, and composting**, or co-composting with yard waste followed by land application. Again, levels of metal contaminants need to be monitored.

- **Drying and disposal on landfills**. It is important that it is dried to avoid generation of large quantities of leachate.

3.8 Industrial waste

Industrial wastes are often disposed of within municipal landfills. Industrial wastes can be extremely varied in content depending on the particular industry the waste is derived from. Sound practice must lead to separation of hazardous industrial waste from MSW, and appropriate disposal. A document by Batstone, et al, as referenced in the bibliography is useful as a general reference for dealing with these wastes.

3.9 Information Sources for the Pacific Region

(a) The World Health Organisation (WHO) have significant information on waste management issues and in particular how these impact on human health. They can be contacted by writing to:

Avenue Appia 20
1211 Geneva 27
Switzerland

Telephone: (+00 41 22) 791 21 11
Facsimile (fax): (+00 41 22) 791 3111

Their Internet address is http://www.who.int.

(b) In the Pacific Region, the main information sources on solid liquid and hazardous waste are SPREP, SOPAC, UNCHS-Habitat, and in a more general way, UNEP-IETC.

SPREP is currently completing two projects, which will assist with the management of hazardous wastes. The first of these is the AusAID funded 'Management of Persistent Organic Pollutants in Pacific Island Countries' (POPs in PICs) project. SPREP should be contacted for further information relating to these projects.

SPREP (South Pacific Regional Environment Programme)
POBox 240, Vaitele, Apia, Samoa

Tel: (685) 21929 Fax: (685) 20231

E-mail: sprep@sprep.org.ws
Web site: http://www.sprep.org.fj

(c) The NZODA funded 'Development of Hazardous Waste Management Strategy in Pacific Island Countries' project will develop and implement long-term hazardous waste management plans to allow countries to effectively deal with potentially toxic materials entering the region. This will be a good source of information on hazardous waste management. NZODA can be found on the web at http://www.mft.govt.nz/nzoda/nzoda.html or contacted by post at:

Development Cooperation Division
Ministry of Foreign Affairs and Trade
Private Bag 18 901
Wellington
NEW ZEALAND

Telephone 64 4 494 8500
Facsimile 64 4 494 8514

(d) UNCHS or (Habitat) have significant resources available on waste handling and disposal technologies. They can be contacted by post at:

UNCHS (Habitat)
P.O.Box 30030
Nairobi, Kenya

Tel: (254-2) 621234
Fax: (254-2) 624266

E-mail: habitat@unchs.org
URL: http://www.unchs.org

UNEP web site: http://www.unep.org/

(e) South Pacific Applied Geoscience Commission
SOPAC
Private Mail Bag,
General Post Office
Suva, FIJI

Web site: http://www.sopac.org.fj/

(f) Bastone, Roger, "The Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries. World Bank Technical paper Number 93. Washington: World Bank, 1989.

(g) US Contacts:

National Small Flows Clearinghouse
West Virginia University Clearinghouse
West Virginia University
P.O. Box 6064
Morgantown, WV 26506-6064

Web site: www.nesc.wvu.edu

Centre for Environmental Research information
26 W. St. Clair
Cincinnati, OH 45268

(h) US Pacific Islanders are covered by the following Regional USEPA Office

US Environmental Protection Agency – Region IX
215 Fremont St.
San Francisco, CA 94105

4 Wastewater Technologies

4.1 Introduction

There are numerous technologies to deal with the disposal of wastewater throughout the world. Many of these technologies have been used in the Pacific however, for many reasons have failed. These reasons include inappropriate technology, insufficient operation and maintenance practices, lack of funding and lack of skilled personnel to name a few. This section will focus on proven sound environmental technologies plus those currently used in the Pacific, grouped under the following headings:

- Wastewater Collection and Transfer;
- Wastewater Treatment (Onsite);
- Wastewater Treatment (Centralised and Decentralised);
- Wastewater Reuse;
- Wastewater Disposal Systems; and
- “Zero” Discharge.

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 Pacific SIDS.

See http://www.cep.unep.org/pubs/techreports/tr40en/index.html for technologies for sewage disposal in the Caribbean SIDS area.

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.

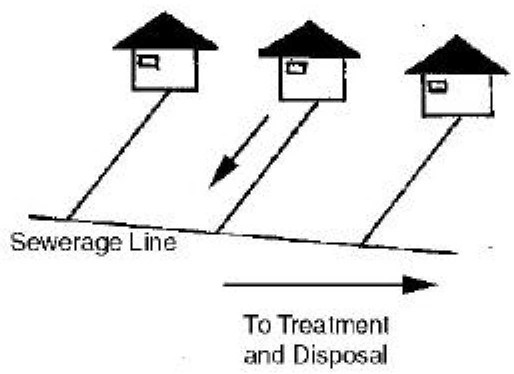
All but a few types of on-site disposal systems requires water to transfer waste throughout the treatment system, thus, the availability of a reliable water supply is a major criteria in selecting the type of wastewater disposal to be used.

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.

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.

Extent of Use:
- most major urban areas in the Pacific 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 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

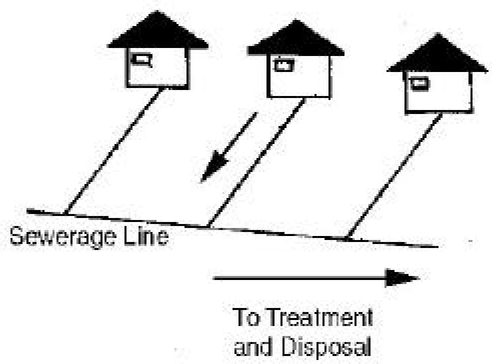
Relative Cost:
- high capital and operation & maintenance costs

Cultural Acceptability:
- is generally accepted within the Pacific Region

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

Collection and Transfer Systems:

Simplified Sewerage



Note: Smaller diameter pipes than 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.

Extent of Use:

- not used often within the Pacific Region

Operation and Maintenance:

- high degree of operation and maintenance required especially if pumping is required
- skilled personnel required
- higher blockage risk than conventional sewerage

Advantages:

- lower capital cost than 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:

- moderate to high capital costs
- moderate operation & maintenance costs

Cultural Acceptability:

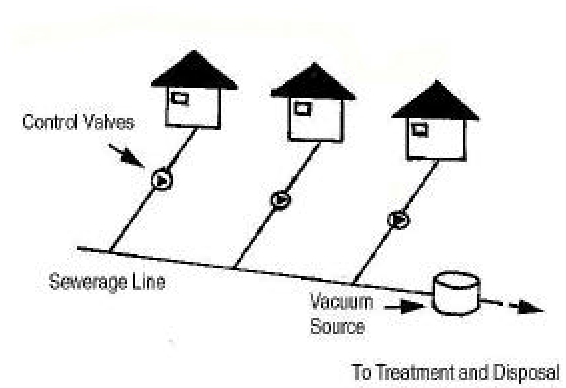
- is generally accepted within the Pacific Region

Suitability:

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

Collection and Transfer Systems:

Vacuum Sewerage



Technology Description:

Vacuum sewerage systems use a central vacuum source to convey sewage from individual households to a central collection station. A valve separates the atmospheric pressure in the home service line from the vacuum in the collection mains. The valve periodically opens based on volume stored to allow wastewater and air to flow into the vacuum collection mains. The wastewater is propelled in the collection main from the differential pressure of a vacuum in front and atmospheric pressure in the back. Eventually the air pressure in the collection main equalises, and all flow ceases until the next valve from a service line is opened. Through this process, wastewater is conveyed to a central collection tank. From there, it can be conveyed by gravity or by a pump station through a force main to its final destination. Vacuum sewers are typically used in low population density areas where the terrain will not permit gravity flow to a central location or treatment facility.

Extent of Use:

- proposed for use in Rarotonga, Cook Islands
- not recommended

Operation and Maintenance:

- high degree of operation and maintenance is required
- skilled personnel required

Advantages:

- lower capital cost than 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
- possible odour problem from venting

Relative Cost:

- high capital costs but less than conventional sewerage

Cultural Acceptability:

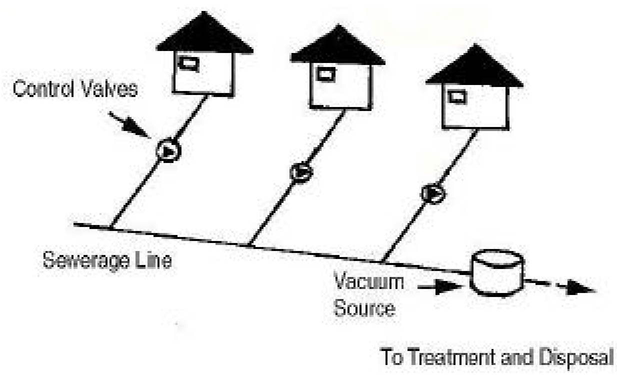
- is generally accepted within the Pacific Region

Suitability:

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

Collection and Transfer Systems:

Settled 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 on 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 than 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.

Extent of Use:
- not often used in the Pacific 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.
- low operation & maintenance costs

Disadvantages/constraints:
- moderate to high capital 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

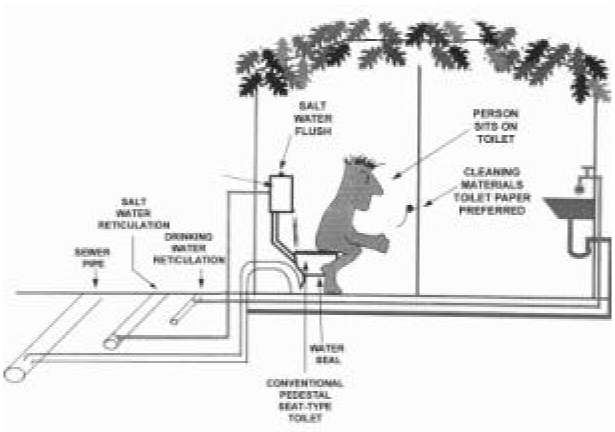
Relative Cost:
- moderate to high capital costs
- low operation & maintenance costs

Cultural Acceptability:
- is generally accepted within the Pacific Region

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

Collection and Transfer Systems:

Saltwater Flushing (Dual Distribution Systems)



Source: ADB

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 (i.e. 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.

Extent of Use:

- in the Pacific, saltwater systems are used in Kiribati, Marshall Islands and Nauru. In the Caribbean, US Virgin Islands, St Lucia and the Bahamas also use saltwater systems

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 purposes reduces the use of limited freshwater resources

Disadvantages/constraints:

- high capital and operation & maintenance costs
- high technology requiring skilled engineers, contractors and operators
- risk of polluting groundwater through leaks
- risk of cross connections

Relative Cost:

- high capital and operation & maintenance costs (due to the duplication of distribution networks and the need to use corrosion-resistant materials)

Cultural Acceptability:

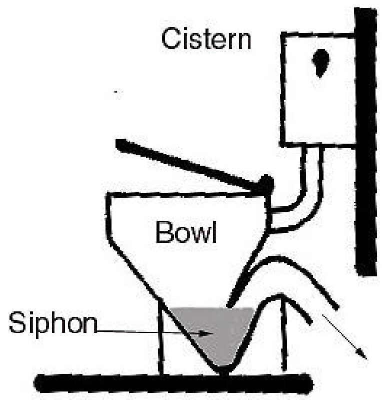
- is generally accepted within the Pacific Region

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.

Extent of Use:

- extensively throughout SIDS

Operation and Maintenance:

- subject to malfunction of flushing system

Advantages:

- easy to use and clean
- hygienic
- low to moderate capital and operation & maintenance costs

Disadvantages/constraints:

- high maintenance
- high water use

Relative Cost:

- low to moderate capital and operation & maintenance costs

Cultural Acceptability:

- no cultural problems

Suitability:

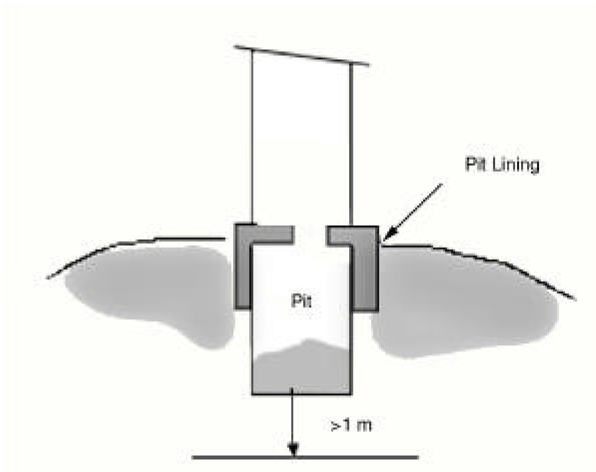
- Very suitable if reliable water supply exists and if it can be afforded by user.

4.3 Wastewater Treatment (Onsite)

Onsite 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. Onsite 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 onsite 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 Sanitation Expert Systems (SANEX) (1998).

Onsite Wastewater Treatment

Pit Latrine



Note: Recommended that minimum distance from the bottom of the pit to the groundwater is at least > 1 m.

Source: T. Loetscher (1998)

Technology Description:

The pit latrine is designed for the onsite 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 and 30 years. If less than 10 years, a double vault composting (DVC) latrine should be considered instead.

The pit diameter is between 1 and 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 requires 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.

Extent of Use:
- extensively used throughout the Pacific 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 cannot receive graywater
- since pit latrines involve soil absorption, there is a danger of groundwater contamination
- odours and insect nuisance may occur

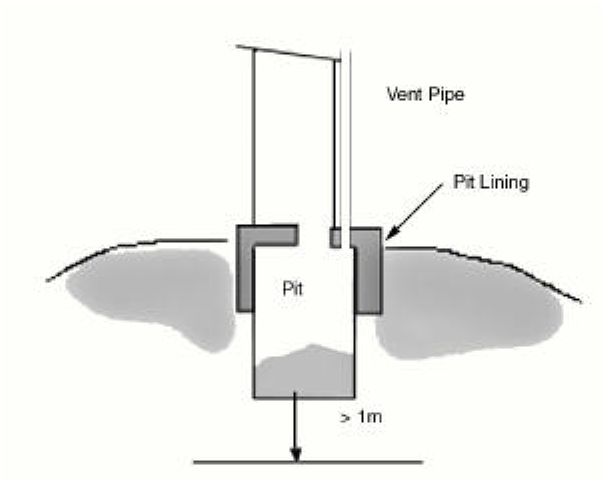
Relative Cost:
- low capital and operation & maintenance costs

Cultural Acceptability:
- culturally accepted

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

Onsite Wastewater Treatment

VIP Latrine



Note: Recommended that minimum distance from the bottom of the pit to the groundwater is at least > 1 m.

Source: T. Loetscher (1998)

Technology Description:

The ventilated improved pit (VIP) latrine is designed for the onsite 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.

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

Extent of Use:
- moderate use in Pacific 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
- no odors
- low cost

Disadvantages/constraints:
- this facility cannot receive graywater
- there is a danger of groundwater contamination
- excreta can be seen through the hole in the squatting plate or riser

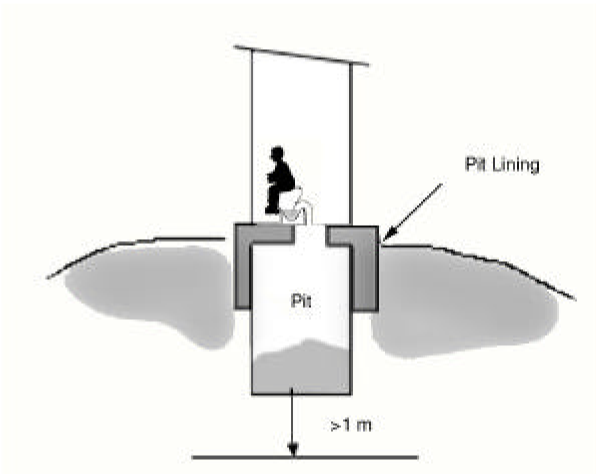
Relative Cost:
- low capital and operation & maintenance costs

Cultural Acceptability:
- culturally accepted

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

Onsite Wastewater Treatment

Pour-Flush Latrine



Note: Recommended that minimum distance from the bottom of the pit to the groundwater is at least > 1 m.

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

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. The toilet pan consists of a siphon, which creates a water seal forming an effective barrier against odours and insect nuisance, and prevents excreta from being seen once flushed. 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

One unit can serve one or several households and if constructed properly, they provide good health benefits.

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

The pour-flush toilet itself has no treatment effects.

Extent of Use:
- used extensively throughout the Pacific

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
- no odours
- low cost

Disadvantages/constraints:
- this facility cannot receive graywater
- since pit latrines involve soil absorption, there is a danger of groundwater contamination

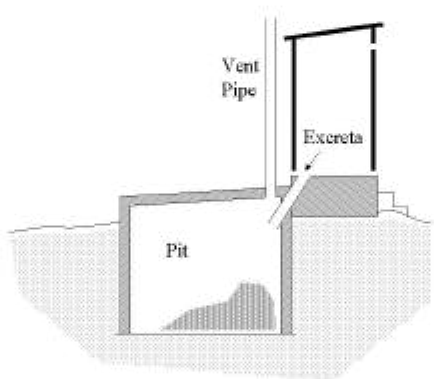
Relative Cost:
- low capital and operation & maintenance costs

Cultural Acceptability:
- culturally accepted

Suitability:
- Suitable for household and community use, however contamination of groundwater may be an issue.

Onsite Wastewater Treatment

Reed Odourless Earth Closet



Source: T. Loetscher (1998)

Technology Description:

The Reed Odourless Earth Closet (ROEC) is designed for the onsite 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 and 30 years. If less than 10 years, a double vault composting (DVC) latrine should be considered instead.

Because it is offset, 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.

ROEC's 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 ROEC's 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.

Extent of Use:
- not used much

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 cannot receive graywater
- fouling of the chute is often a problem
- danger of groundwater contamination

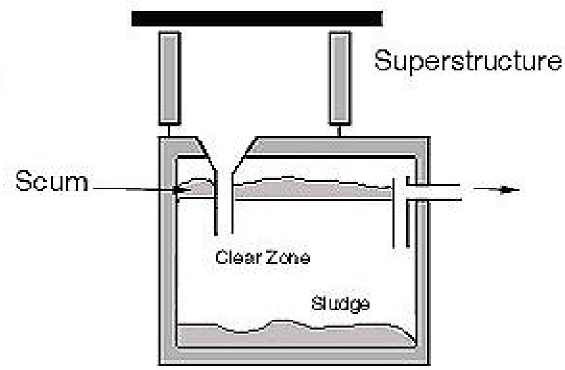
Relative Cost:
- moderate capital costs

Cultural Acceptability:
- culturally accepted

Suitability:
- Suitable in water-short areas however contaminated groundwater may be an issue.

Onsite Wastewater Treatment

Aquaprivy



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

Source: T. Loetscher (1998)

Technology Description:

The aquaprivy is designed for the onsite 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.

Graywater has to be collected and discharged separately.

Extent of Use:
- not used much

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

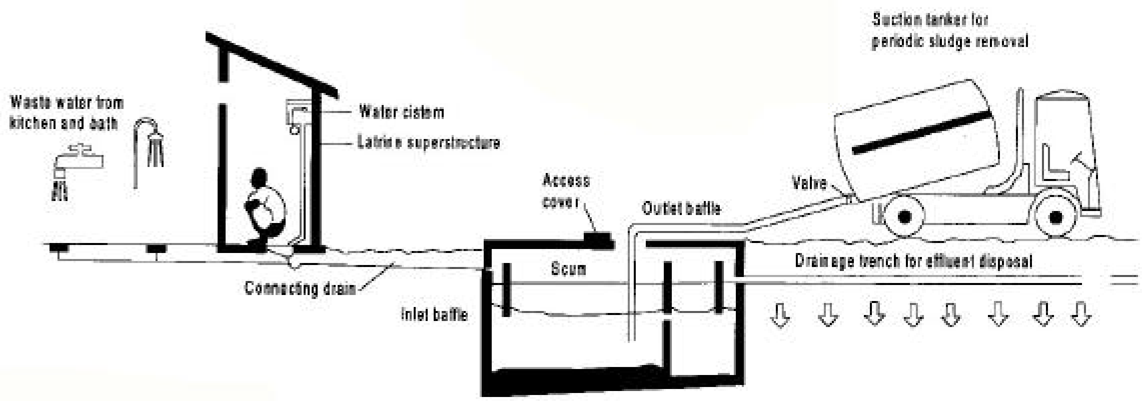
Disadvantages/constraints:
- if not well constructed, tanks are not watertight. As a consequence, it is difficult to maintain the liquid level and thus the water seal, with resulting bad odours, and the risk of groundwater contamination
- high costs

Relative Cost:
- high capital costs

Cultural Acceptability:
- culturally accepted

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

4.4 Septic Tank Systems



Intermediate Technologies, 1991

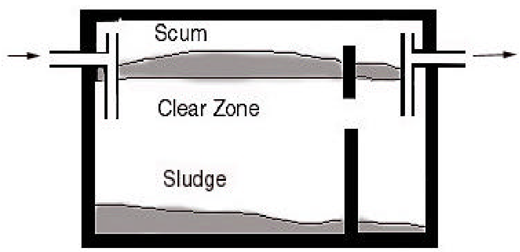
Details of Septic Tank System

Septic tanks are only one component of the septic system. The tank itself only provides minimal treatment with the separation of sinkers and floaters. It must be stressed that there needs to be proper soil treatment as the septic tank doesn't provide full treatment.

- Components
    - Graywater/Blackwater
    - Septic Tanks
    - Drainage fields
    - Seepage systems

Onsite Wastewater Treatment

Septic Tank



Note: Effluent from the septic tank must be disposed of through drainage fields, seepage 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.

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

Technology Description:

The septic tank is designed for the onsite 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.

Extent of Use:

- extensively used in all SIDS

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:

- graywater can be treated together with toilet waste.
- there is some potential for self help
- low land requirements
- no electrical requirements
- low operational and maintenance requirements

Disadvantages/constraints:

- 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:

- low to high capital costs

Cultural Acceptability:

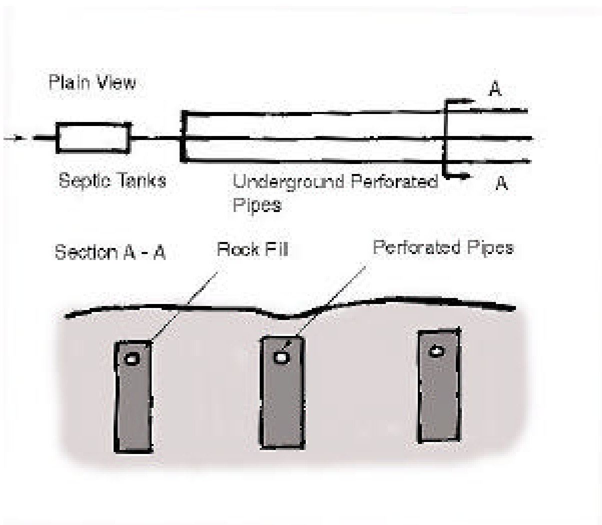
- culturally accepted

Suitability:

- Very suitable if designed, constructed and maintained properly and used with trench drainage system.

Onsite Wastewater Treatment

Drain Field



Source: T. Loetscher (1998)

Technology Description:

The drain field is designed for the onsite 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 graywater.

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.

Extent of Use:

- low 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
- operation & maintenance 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
- low costs

Disadvantages/constraints:

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

Relative Cost:

- low capital costs

Cultural Acceptability:

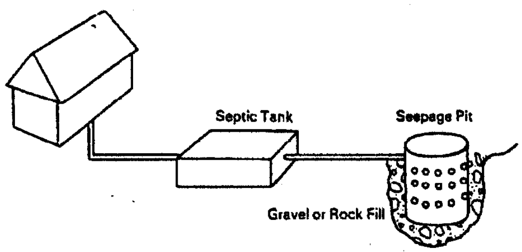
- culturally accepted

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).

Onsite Wastewater Treatment

Seepage Pit



Note: In the Pacific seepage pits often 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 graywater.

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

Extent of Use:

- seepage (or soakage) pits are extensively used in the Pacific, however are not built to the standard shown here

Operation and Maintenance:

- if constructed properly, minimal maintenance is required
- operation & maintenance 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 than with drainage trenches, as effluent is concentrated at one point rather than spread over a large area

Relative Cost:

- moderate capital costs

Cultural Acceptability:

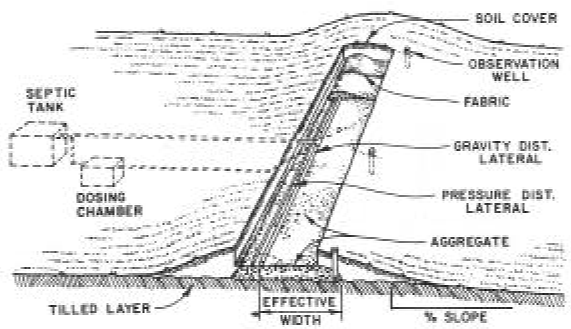
- culturally accepted

Suitability:

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

Onsite Wastewater Treatment

Wisconsin Mound (raised bed)



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.

Source: Tyler & Peterson

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 600 mm) to ensure satisfactory renovation before entering the natural soil to then diffuse into the water table. 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 graywater.

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

Extent of Use:

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

Operation and Maintenance:

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

Advantages:

- the construction of Wisconsin mounds is simple with good potential for self help
- better disposal method than seepage pits
- increases the evapo-transpiration rate

Disadvantages/constraints:

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

Relative Cost:

- high capital costs

Cultural Acceptability:

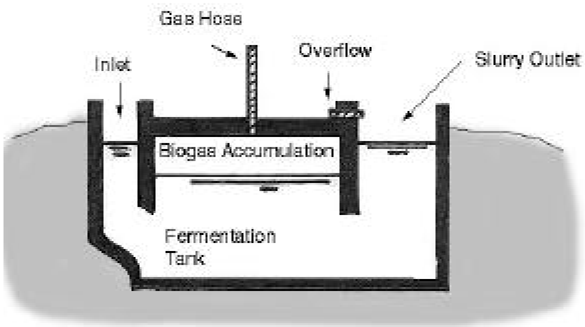
- culturally accepted

Suitability:

- Very suitable for disposing 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).

Onsite Wastewater Treatment

Biogas Digester



Source: T. Loetscher (1998)

Technology Description:

The biogas digester is an onsite facility, which produces biogas (mainly methane) that can be used for cooking and lighting. Since the technology does not work well with human excreta alone, it is only suitable for rural areas where large animals (e.g. pigs or cattle) are held.

The rather large fermentation tank (approximately 10 cubic metre for a single household) is fed with human excreta (e.g. from a pour-flush toilet), diluted animal faeces, and crop stalks.

A well designed and operated digester produces enough gas to cover the needs of an entire household. Because of the long liquid retention time, the effluent slurry may be safely used as fertilizer in agriculture and aquaculture. Graywater can be used to dilute animal faeces.

However, larger units serving several households or a whole commune are also feasible.

Significant amounts of water are required to dilute animal faeces.

Biogas production falls off at low ambient temperatures. It is thus advantageous to bury the tank. Biogas digesters are not suitable for cold climates (i.e. winter temperatures significantly below zero for a prolonged period of time).

This technology is not suitable for areas with no demand for biogas or where no farm animals are kept (i.e. no animal faeces are available).

Extent of Use:
- minimal use in Pacific Region

Operation and Maintenance:
- similar to a septic tank; must be de-sludged every 3 to 5 years for optimal performance

Advantages:
- provide source of biogas
- animal waste may be use as well

Disadvantages/constraints:
- skilled labour is required for the construction of a watertight tank, with little scope for self help
- requires large source of faeces for biogas production
- better disposal method than seepage pits
- high costs

Relative Cost:
- high capital costs

Cultural Acceptability:
- culturally accepted

Suitability:
- Yes, where animal manure is available and where biogas is in demand.

4.5 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.

4.5.1 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. However in some Pacific SIDS preliminary treatment is the only form of treatment before being discharged into the sea.

4.5.2 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.

4.5.3 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 pretreating industrial effluents.

4.5.4 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.

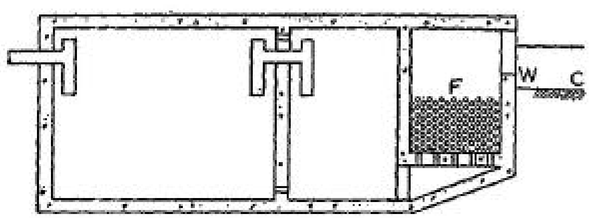
Most “package” plants available provide secondary treatment. However when used in conjunctions with another secondary treatment process may provide tertiary treatment.

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

Primary Process

Septic Tank

Septic Tank with Upflow Filter
Longitudinal Section



F – Filter
W – Effluent Weir
C – Effluent Channel

Source: Septic tank with upflow filter after Mara, D

Technology Description:

This is essentially a septic tank with an Upflow Filter that is incorporated directly after the second chamber of the septic tank. Effluent after leaving the second chamber of the septic tank is directed upwards through the bottom of the filter before exiting to be disposed of either in leach fields etc. It is also mainly designed for on-site treatment of domestic sewage. In the upflow filter the effluent enters at the base and flows up through the layer of coarse aggregate which is then discharged over a weir at the top. Anaerobic bacteria grow on the surface of the filter material and oxidise the effluent as it flows past. Disposal of the effluent may be into a stream or into soakage pits etc.

The effluent can have up to 70 % reduction in BOD and it changes a malodorous highly turbid, grey to yellow influent to an odourless clear light yellow effluent.

Both graywater and blackwater can be flushed through the system.

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

Extent of Use:

- limited use in the Pacific Region

Operation and Maintenance:

- filter may be expected to operate without maintenance for 18 to 24 months; then need to drain filter and wash with freshwater
- septic tank needs regular desludging. Filter and the septic tank can be cleaned together

Advantages:

- low land space required
- no electrical requirements
- low operational and maintenance requirements
- construction material locally available

Disadvantages/constraints:

- construction of septic tank and upflow filter requires skilled labour

Relative Cost:

- moderate capital costs

Cultural Acceptability:

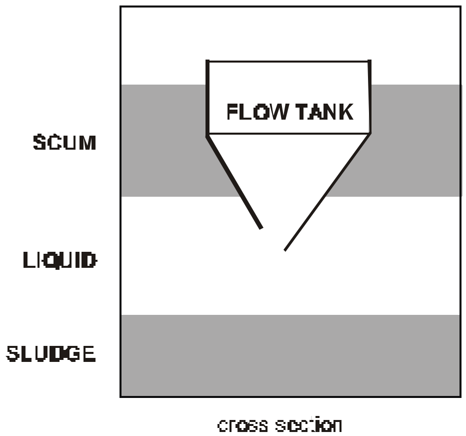
- is generally accepted within the Pacific Region

Suitability:

- Not suitable where water supply scarce or unreliable.

Primary Process

Imhoff Tanks



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, it 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 graywater and blackwater can be flushed through the system.

Extent of Use:
- limited use in the Pacific 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
- construc tion material locally available
- low costs

Disadvantages/constraints:
- effluent still contaminated with pathogens
- needs skilled contractors for construction of Imhoff tanks
- poor effluent quality

Relative Cost:
- low capital costs

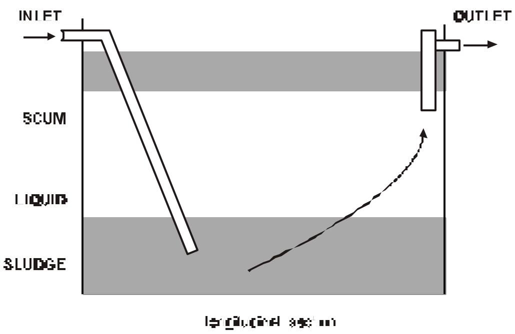
Cultural Acceptability:
- is generally accepted within the Pacific Region

Suitability:
- Not suitable where water supply is scarce or unreliable.

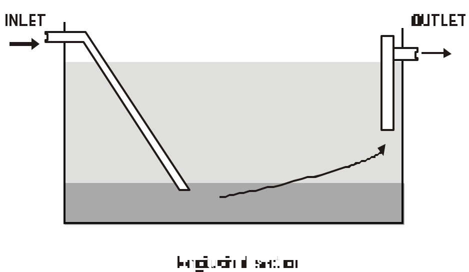
Primary Process

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 and 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 graywater and blackwater can be flushed through the system.

Extent of Use:

- limited use in the Pacific Region

Operation and Maintenance:

- apart from being filled with water before use the start up of 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
- low to moderate capital costs with low operation & maintenance costs

Disadvantages/constraints:

- poor effluent quality for low loaded ponds with short Hydraulic Retention Times (HRT) or domestic water
- low effluent quality for small ponds treating domestic wastewater

Relative Cost:

- low to moderate capital costs
- low operation & maintenance costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

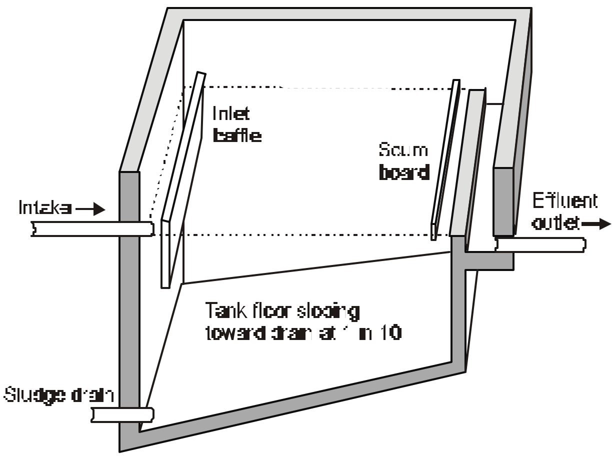
Suitability:

- 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 Ponds

Ponds/Tanks

Sediment 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; and
- low loaded tanks with long Hydraulic Retention Times 98 % BOD removal, 96 % COD removal.

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

Extent of Use:

- limited use in the Pacific Region

Operation and Maintenance:

- sludge removal is important and must be done regularly
- other then desludging no significant maintenance required

Advantages:

- no electrical requirements
- low operational and maintenance requirements
- construction material locally available
- high effluent quality for low loaded tanks with long HRT
- low to moderate capital costs with low operation & maintenance costs

Disadvantages/constraints:

- low effluent quality for low loaded tanks with short HRT

Relative Cost:

- low to moderate capital costs
- low operation & maintenance costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

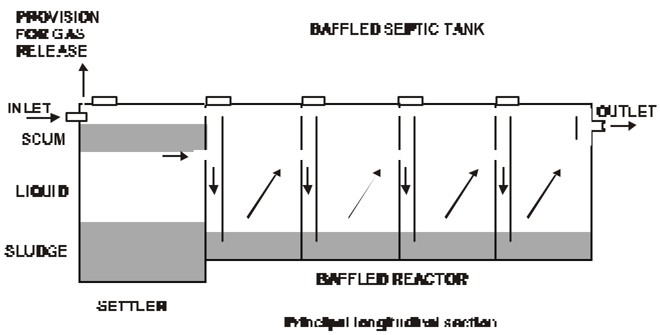
Suitability:

- 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

Reactors

Baffled Septic Tanks



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

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

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Technology Description:

This process is suitable for all kinds of wastewater including domestic. The baffled septic tank consists of an initial settler compartment and a second section of a series baffled reactors. Sludge settles at the bottom and the active sludge that is washed out of one chamber becomes trapped in the next. The reason for the tanks in series is to assist in the digestion of difficult degradable substances especially towards the end part of the process. For the purpose of quicker digestion, effluent upon entering the process is mixed with active sludge present in the reactor. Wastewater flows from bottom to top causing sludge particles to settle on the upflow of the liquid wastewater allowing contact between sludge already present with incoming flow. A settler can be used for treatment after effluent has left the tank. Hydraulic and organic shock loads have little effect on treatment efficiency.

The treatment efficiency achievable is 70-95 % BOD removal, 65-95 % COD removal and the resulting effluent quality is moderate.

Extent of Use:

- limited use in the Pacific Region

Operation and Maintenance:

- sludge removal is important and must be done regularly
- flow regulation is also important as up-flow velocity should not exceed 2 m/h
- moderate operation and maintenance requirements

Advantages:

- no electrical requirements
- construction material locally available
- low land space required
- low capital costs

Disadvantages/constraints:

- needs skilled contractors for construction

Relative Cost:

- low capital costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

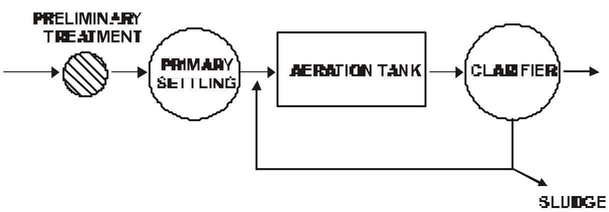
Suitability:

- Not suitable where water supply is scarce or unreliable.

Secondary Process

Activated Sludge Treatment

Activated Sludge Treatment



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 graywater.

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

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

Extent of Use:

- limited use in the Pacific Region

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 requirement
- high effluent quality

Disadvantages/constraints:

- needs skilled contractors for construction
- importation of some construction material
- needs trained operator
- requires electricity
- high operation and maintenance
- high capital and operation & maintenance costs

Relative Cost:

- high capital and operation & maintenance costs.

Cultural Acceptability:

- is generally accepted within the Pacific Region

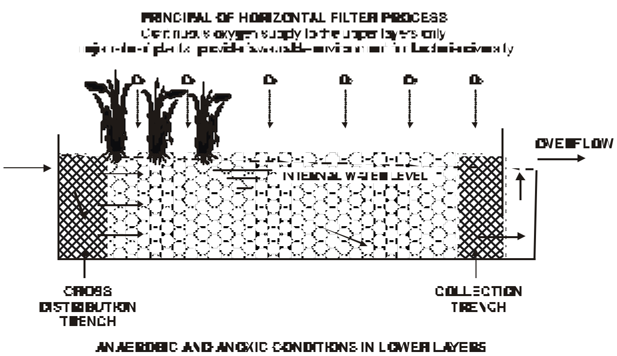
Suitability:

- Not suitable where water supply is scarce or unreliable as requires high volumes of water for transportation to treatment site.
- Yes, where technical backup is available.

Secondary Process

Wetlands/Ponds

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



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 500 mg/l. The reed bed system is 1-m 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.

Extent of Use:

- limited use in the Pacific Region

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
- creates environment for insect breeding
- moderate to high costs

Relative Cost:

- moderate to-high capital costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

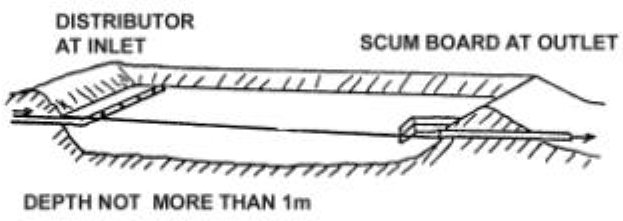
Suitability:

- Since only receive liquid waste, not suitable where water is 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., Williamson, 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.

Extent of Use:

- limited use in the Pacific 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:

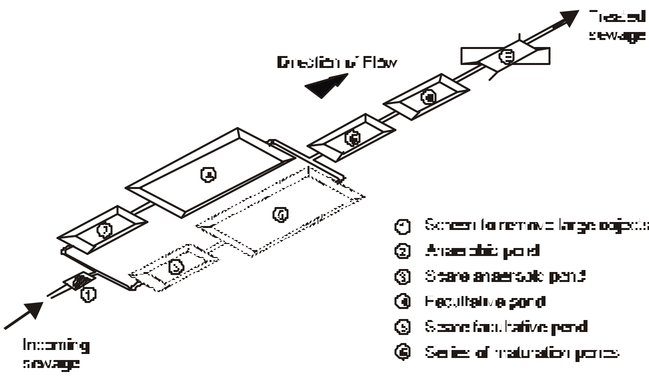
- moderate capital costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

Suitability:

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

Secondary Process **Ponds** Waste Stabilisation Ponds  **Note: Need to keep top layer aerobic, oxygen sufficient all the time** Source: After Pickford, J., 1991n	**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 the 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. **Extent of Use:** • limited use in the Pacific Region

Operation and Maintenance:
- grass around ponds need to be cut regularly
- regular desludging is required

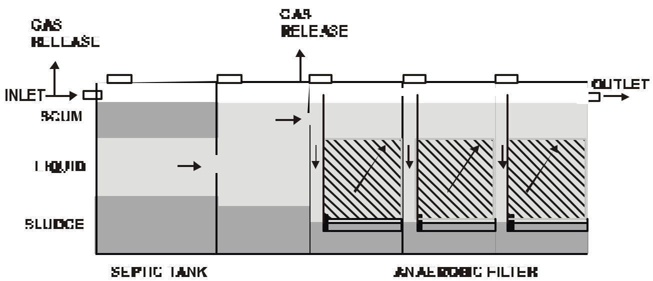
Advantages:	**Disadvantages/constraints:**
• low operation and maintenance • no electrical requirement • construction material locally available • high effluent quality	• high land space required
Relative Cost: • moderate capital costs	**Cultural Acceptability:** • is generally accepted within the Pacific Region

Suitability:
- Since only receive liquid waste, is not suitable where water is scarce or unreliable.

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 graywater and blackwater can be flushed through the system.

Extent of Use:
- limited use in the Pacific 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
- high costs

Relative Cost:
- high capital costs

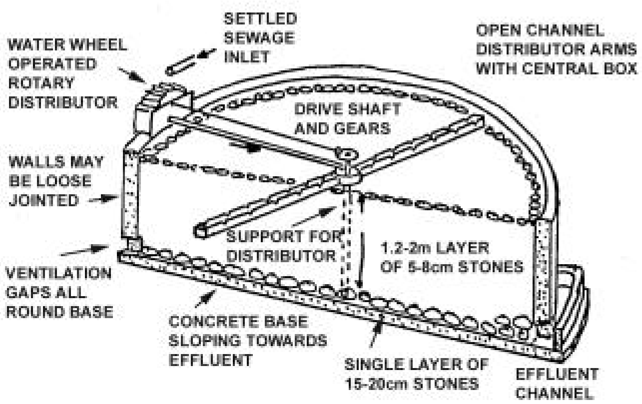
Cultural Acceptability:
- is generally accepted within the Pacific Region

Suitability:
- Since only receive liquid waste, is not suitable where water is scarce or unreliable.
- Yes, where technical backup is available.

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 1 kg BOD/m^3 x d.

Extent of Use:

- limited use in the Pacific 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 requirements
- needs electrical power
- moderate to high costs

Relative Cost:

- moderate to high capital costs
- moderate operation & maintenance costs

Cultural Acceptability:

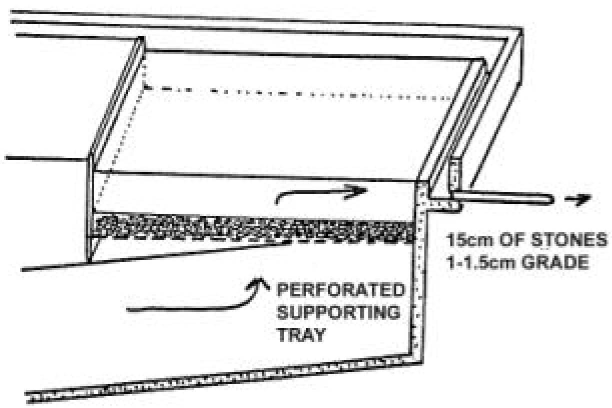
- is generally accepted within the Pacific Region

Suitability:

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

Tertiary Process

Banks' Clarifiers



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

Technology Description:

Banks' Clarifiers are a compact tertiary treatment process. It is essentially an upward flow filter containing a bed of gravel that is supported on a perforated base. The accumulation of solids occur within and on the upper surface of the gravel layer. The bed should be cleaned when the upper surface is covered or when suspended solids concentration in the final effluent rises.

Typical effluent treatment quality performed on secondary treated effluent is 30 % BOD removal, 50 % Suspended solids removal and 25 % E. Coli removal.

Extent of Use:

- limited use in the Pacific Region

Operation and Maintenance:

- requires removal of solids, which accumulate on the upper surface of the gravel bed layer

Advantages:

- low operation and maintenance
- construction material available locally
- no electrical requirement
- high effluent quality

Disadvantages/constraints:

- high land space required
- high volume of water required

Relative Cost:

- moderate capital and operation & maintenance costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

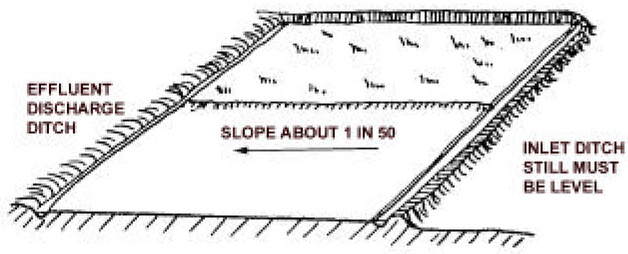
Suitability:

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

Tertiary Process

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.

Extent of Use:

- limited use in the Pacific 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 volumes of water required

Relative Cost:

- moderate capital and operation & maintenance costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

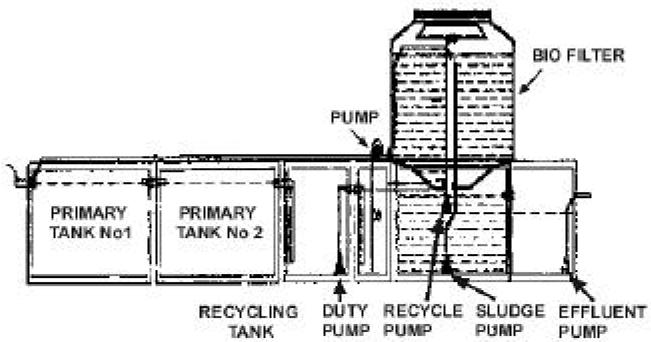
Suitability:

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

Package Plant Types

Plant Type

Enviroflow Biofilter Treatment Plant System



Source: After Enviroflow Wastewater Treatment Brochure, 1989

Technology Description:

Enviroflow Plants treat both black and graywater 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 < 20 mg/l and Suspended Solids < 30 mg/l

Extent of Use:

- limited use in the Pacific 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 volumes of water requirement
- high operation and maintenance
- requires electricity
- high costs

Relative Cost:

- high capital and operation & maintenance costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

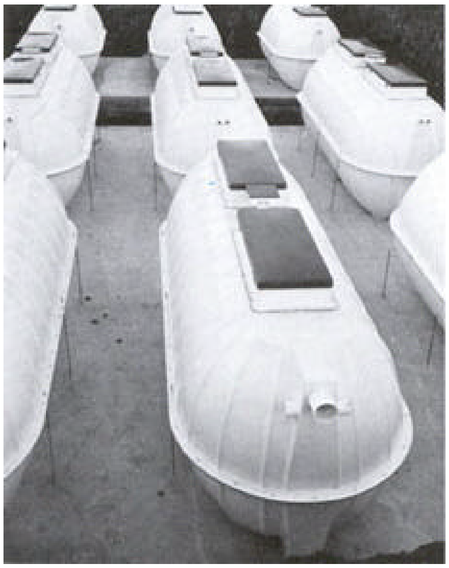
Suitability:

- Since only receive liquid waste, is not suitable where water is scarce or unreliable.
- Yes, where technical backup is available.

Package Plant Types

Plant Type

Sequential Batch Reactors Cromaglass Unit



Source: After Cromaglass Wastewater Treatment System, 1998.

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) an 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 – 30 mg/L, Total Suspendable Solids 30 mg/L.

Extent of Use:
- limited use in the Pacific 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 inputs
- high costs

Relative Cost:
- high capital and operation & maintenance costs

Cultural Acceptability:
- is generally accepted within the Pacific Region

Suitability:
- Since only receive liquid waste, is not suitable where water is scarce or unreliable.
- Yes, where skilled technical backup is available.

4.6 Waterless toilets

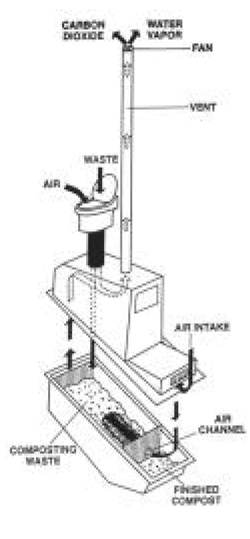
Waterless toilets or 'dry sanitation' systems do not use water to treat or transport human excreta. These systems, if appropriately designed, conserve precious water resources and avoid disposal of effluent and pollutants into waterways and the general environment. They are an important onsite alternative to centralised reticulated systems, which remove the problem 'downstream'. They can also reduce the site restrictions and pollution problems that can be encountered in the use of waterborne onsite systems such as septic tanks. Waterless toilets can produce a useful soil improver that is hygienic to use if the required time and conditions have allowed treatment to occur.

The most common type of waterless toilet is often referred to as a 'composting toilet' (CT) although the treatment often involves more than the process that occurs in the garden compost heap. Decomposition in the holding tank or container of a CT occurs through a complex bio-chemical interaction of factors such as temperature, pH, dessication, and digestion by invertebrates, all taking place over an extended time period.

There are many designs of CT but they can be divided into two main types and they have characteristic advantages and disadvantages which are summarised below. The range of designs include commercial off-the-shelf units and owner-built systems that can be constructed using locally available materials.

4.6.1 Continuous Composting Toilets

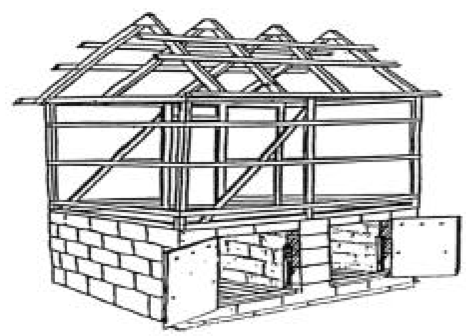
Consist of a single container in which excrement is deposited by the user, and as it moves slowly through the container it decomposes, and then is removed as compost from the end-product chamber. Examples of the off-the-shelf system are the Clivus Multrum (see below), which is one of the earliest CT designs and has had different many models over the years, some more successful than others, and an owner-built example is the Clivus Minimus.



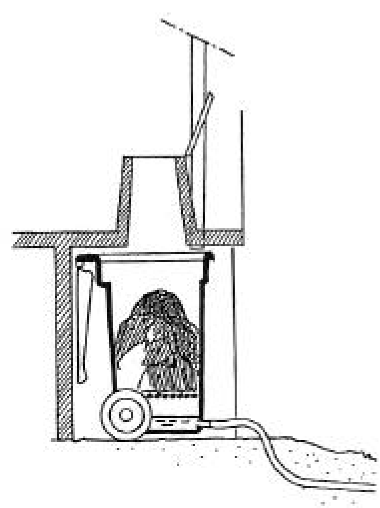
Continuous system

Advantages: single containers are fitted under a bathroom and can easily replicate a flush toilet without too much physical or social adjustment. The container is permanently fitted under the toilet seat, and also never has to be fully emptied as the compost can be gradually removed when it reaches the end-product chamber.

Disadvantages: the continuous system may allow fresh material and pathogens (disease causing organisms) that are deposited on the top of the pile to contaminate the bottom of the pile, which may have already successfully decomposed. If a problem occurs with the toilet, the system can be out of order until the problem is fixed because there is only one container. Sometimes the pile does not actually move down the slope of the container and the excreta can become compacted, and very difficult to remove



Fixed chamber batch used in Tonga, Kiribati and Australia



Example of movable bins in a wheelibatch system

4.6.2 Batch Composting Toilets

Consists of two or more containers that are alternated so that the 'active' container is being used while the pile in the 'fallow' container has time to compost without the addition of fresh excrement and the potential for re-contamination. Examples of owner-built Batch CTs are the Wheelibatch where the containers are alternated underneath the toilet seat, and the Fixed Chamber Batch where the two containers are permanently in place and the seat is moved when it is time to change containers.

Advantages: Multiple containers increase maintenance flexibility as the containers can be alternated if they fill up faster than expected. It is possible to keep using the toilet and still be sure that the pile is fully decomposed before removing the end-product.

Disadvantages: the full containers in the batch system need to be replaced by an empty container. This involves disconnecting the container that is fitted under a toilet seat or moving the seat over a new container. Batch systems can therefore take up more space in the bathroom or under the house.

4.6.3 Maintenance of CTs

The CT is relatively simple, technically, but it requires more attention than a flush toilet where you push the button and your excreta is transported elsewhere.

- Some carbon based material or 'bulking agent' such as dry leaves or softwood shavings needs to be regularly (preferably daily or with each use) added to the container to provide the proper carbon-nitrogen mix and to aerate the pile and prevent compacting. Some commercial suppliers say this is not necessary for their design but experience indicates the addition of bulking agent is desirable to produce a good end-product.

- If a CT is working well it should not smell. Offensive odours usually indicate that something is wrong and trouble-shooting directions need to be followed. Often adding bulking agent in greater quantities or more regularly will cure the smell.

- The pile in a CT needs to be well drained and the liquid run-off is often treated in a sealed evapotranspiration trench or a solar evaporating tray.

- The end-product, or compost, needs to be removed from the CT container when it is sufficiently decomposed. The frequency of removal depends on the size of container, how often the system is used and local climatic conditions. The minimum 'fallow' period should be six months. Depending on the design and usage the container usually needs to be emptied every six months to three years.

- The end-product or compost can be used as soil improver buried around trees in the garden

- CTs do not deal with graywater (effluent from showers, kitchen, laundry) so a separate collection system should be provided to re-use the water in the garden

4.6.4 Choosing a CT

- If it is to be built locally which is preferable, choose a design that uses local materials and has been used in similar conditions e.g. The Town Officer and a village committee in Tonga have built a simple batch system for each house (41 houses) based on a 3-year trial in another part of Tonga, all materials used are available locally. This also stimulates the local economy.

- If you want an off-the-shelf unit contact a number of suppliers and tell them about the building where the toilet will be located, how many people will be using the toilet, and whether it will be on a continuous basis or occasionally such as in a bush house, and ask them to recommend a suitable system and give you a quote.

- Check whether the supplier will give after-sales support. Ask them if they have any customers with whom you could discuss their experience with the CT.

- Refer to the website www.compostingtoilet.org which has extensive information on CTs including worldwide contacts for commercial units and owner-built designs. Check out the references listed below.

- Choose a design that has been in operation for at least 5 years. The cycle of usage and production of compost or end-product can take a couple of years so it is important to know that all stages of the process have been satisfactory.

- Avoid complicated designs, simple passive systems with minimum moving parts are often easier to build, monitor and maintain.

4.6.5 Acceptance

A new type of toilet takes lots of time to be accepted (in any society) and will only happen with repeated experience of the benefits of the system, e.g. saving money on water bills, getting a free soil improver, being able to safely use the well because the groundwater is not polluted by the pit latrine or the septic flush. A comprehensive participatory education program is necessary for introduction of the new system and should include hygiene issues as well as practical maintenance assistance.

The main obstacle with introduction and maintenance of composting toilets is that they are relatively unknown, and require some change in toilet usage and habits. These very personal attitudes, which are ingrained at an early age, are difficult to modify and require time and patience and persuasive incentives. As one PIC Community Health officer remarked “it took us 20 years to get used to the flush toilet, at first we didn’t like it for a lot of reasons.”

In PIC communities where the CT has been trialed, people have been very critical at first but then changed their minds over time when they experienced the benefits.

The cost has been reduced as the design has been adapted to local conditions.

4.7 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 Pacific Region. With many SIDS 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.

There is potential in Fiji to use wastewater to irrigate sugarcane and/or for fish farming that has been recently established there. However these rural activities are generally remote from urban centres where treated wastewater is available. SIDS priorities to provide appropriate and affordable sanitation facilities should explore all possibilities to reuse wastewater wherever possible.

In many SIDS and especially in Papua New Guinea, there are strong traditional feelings against the re-use 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. Also, irrigation is not practised extensively in the Pacific and therefore water for irrigation use is not a high priority in most SIDS.

Wastewater is a valuable resource and its re-use 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 re-use of wastewater is safe for those who use re-used wastewater and those who consume food products grown with re-used wastewater. (i.e. eating contaminated crops or eating animals that have fed on contaminated crops or developed in wastewater ponds).

For additional information on the re-use 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 Re-use

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 re-use 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 re-use, the type of wastewater; the potential use of the re-used 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, graywater and septic tank effluent can be used to irrigate lawns and gardens without much cost.

Extent of Use:

Not used much in the Pacific

Level of Involvement

This technology requires engineers and highly skilled plant operators for both construction and operation of re-use 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 re-use.

Advantages

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

Disadvantages

Wastewater re-use carries a potential public health risk when directly re-used for potable use or indirectly re-used 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 re-use 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 re-use; 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).

4.8 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 Pacific SIDS 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.

4.8.1 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 SIDS. The regional organisation, SOPAC, has both the expertise and equipment to implement outfall location investigations.

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 significant health, culture and economic consequences.

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

Tarawa, Betio Outfall showing Ventilation Pipe.

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 4: Land Disposal Methods

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 3785 m^3/day flow
c Range includes raw wastewater for secondary effluent, higher rates for higher level of pre-application treatment.
d With restricted public access; crops not for direct human consumption
e With restricted public access

Source: Opus Environmental Training Centre, Principle and Trends in Wastewater Treatment Manual (1998)

Table 5: Comparison of Typical Effluent Qualities from Land Disposal Methods

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

Source: Opus Environmental Training Centre, Principle and Trends in Wastewater Treatment Manual (1998)

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.

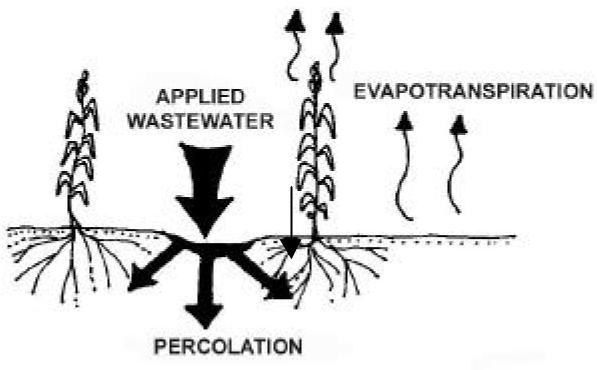
Table 6: Factors affecting choice of irrigation method, and special measures required when wastewater is used.

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 50-100 m 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

Source: Mara and Cairncross, (1989)

Land Treatment

Slow Rate Process



Note: Recommended that groundwater is at least 1 m (or 4ft) below the point of application.

Note: There are strong odors if not set up correctly.

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 50 mm/hr and a depth of a minimum of 1 m 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 evapo-transpiration and percolation. There is a need for vegetation with Slow Rate Process.

Slow Rate Process requires suitable vegetation on the ground to uptake the applied wastewater.

There is a high potential for horticulture.

Extent of Use:

- limited use in the Pacific Region

Operation and Maintenance:

- requires regular operation and maintenance input
- a fence needs to be erected to close off area

Advantages:

- low operation and maintenance
- no electrical requirement
- construction material locally available

Disadvantages/constraints:

- high land space required

Relative Cost:

- low to moderate capital and operation & maintenance costs (land, and irrigation costs)

Cultural Acceptability:

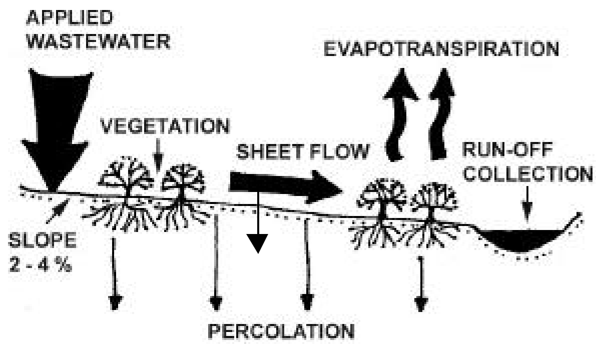
- is generally accepted within the Pacific Region

Suitability:

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

Land Treatment

Overland Flow Process



Note: Recommended that groundwater is at least 1 m (or 4ft) below the point of application.

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 5 mm/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.

Extent of Use:

- limited use in the Pacific Region

Operation and Maintenance:

- requires occasional operation and maintenance input

Advantages:

- low operation and maintenance
- no electrical requirement
- construction material locally available

Disadvantages/constraints:

- high land space required

Relative Cost:

- low to moderate capital and operation & maintenance costs

Cultural Acceptability:

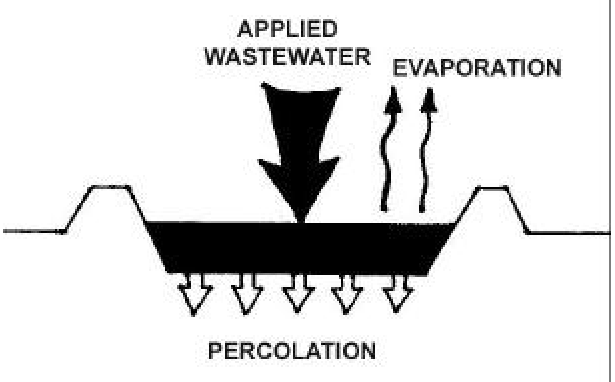
- is generally accepted within the Pacific Region

Suitability:

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

~~Land Treatment~~

Rapid Infiltration Treatment Process



Note: Recommended that groundwater is at least 3 m below the point of application.

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 50 mm/hr. The depth to groundwater should be a minimum of 3 m 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.

Extent of Use:

- limited use in the Pacific Region

Operation and Maintenance:

- requires regular operation and maintenance input.

Advantages:

- low operation and maintenance
- no electrical requirement
- construction material locally available
- high effluent quality
- system can be used to recharge groundwater

Disadvantages/constraints:

- high land requirement
- potential of pollution of groundwater lenses

Relative Cost:

- low to moderate capital and o & m costs

Cultural Acceptability:

- is generally accepted within the Pacific Region

Suitability:

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

4.9 "Zero" Discharge

Regarding human waste the closest technology to achieve a "zero" discharge into the environment is the composting toilet. This technology has already been described in Section 4.3 above.

Composting toilets are an on-site sewage management technology that can offer significant protection for water quality and quantity since the toilets provide dry, biological treatment of human excrement and do not generate quantities of contaminated water that must be discharged into the environment. The excrement in a composting toilet is contained in bins so the waste is not in contact with the groundwater. Composting toilet design can be adapted to local social and physical circumstances as long as the basic conditions for composting are maintained and the protection of public health and the environment is assured. About four months is required for effective composting and treatment of disease-causing organisms, at the end of which time, the excrement has changed its appearance and odour to that of compost, which can be used as a fertiliser or soil conditioner.

This technology ideally suits low-lying atolls with shallow groundwater lenses that are subject to pollution. Because the composting toilets do not require water, limited freshwater resources are not wasted to flush toilets, and consequently there is no wastewater to pollute groundwater resources. In addition the composted waste material is a valuable resource to improve the growing potential of the existing weak sandy soils.

A good reference on composting toilets by David Del Porto and Carol Steinfeld (1999). *The composting toilet system book: a practical guide to choosing, planning and maintaining compost toilet systems, a water-saving pollution-preventing alternative.*

For more information on "zero" discharge and systems that approach "zero" discharge, visit the Integrated Bio-System Network at http://www.ias.unu.edu/proceedings/icibs/ibs/ibsnet/. Also the Greenpeace Pacific 1996 publication, *Sewage Pollution in the Pacific,* provides additional information on "zero" discharge systems.

Table 7: **Technologies Cost Table.**

Technology	Capital Cost	Operation and Maintenance Cost
COLLECTION AND TRANSFER SYSTEMS		
Conventional Sewerage	High	High
Simplified Sewerage	Moderate to High	Moderate
Vacuum Sewerage	High but less than Conventional Sewerage	N/I*
Settled Sewerage	Moderate – High	Low
Saltwater Flushing/Dual Distribution Systems	High	High
Cistern Flush Toilets	Low to Moderate	Low to Moderate
ONSITE WASTEWATER TREATMENT		
Pit Latrine	Low	Low
VIP Latrine	Low	Low
Pour Flush Latrine	Low	Low
Reed Odourless Earth Closet	Moderate	N/I
Aqua-privy	High	N/I
Composting Toilets		
Enviroloo/ Natureloo/Rotaloo	Low	Low
Septic Tank Usage		
Septic-Disposal Field	Low	N/I
Septic-Seepage Pit	Moderate	N/I
Septic-Wisconsin Mound	High	N/I
Biogas Digester	High	N/I
CENTRALISED AND DECENTRALISED WASTEWATER TREATMENT SYSTEMS		
Primary Process		
Septic Tank with Upflow Filter	Moderate	N/I
Imhoff Tank	Low	N/I
Ponds/Tanks/Lagoons		
Small Anaerobic Ponds treating domestic wastewater	Low to Moderate (dependent on cost of land)	Low
High loaded Anaerobic Ponds with long HRT	Low to Moderate (dependent on cost of land)	Low
Low loaded Anaerobic Ponds with short HRT.	Low to Moderate (dependent on cost of land)	Low
Low loaded Anaerobic Ponds with long HRT	Low to Moderate (dependent on cost of land)	Low
Low loaded Sedimentation Tanks with short HRT	Low to Moderate (dependent on cost of land)	Low
Low loaded Sedimentation Tanks with long HRT	Low to Moderate (dependent on cost of land)	Low
SECONDARY PROCESS		
Baffled Septic Tank	Low	N/I
Activated Sludge Treatment	High	High
Ponds/Beds		
Reed Bed System/(SSF) Subsurface Flow Wetlands/Root Zone TP/Horizontal Gravel Filter	Moderate to High	N/I
Aerobic Stabilisation Ponds/Oxidation Ponds/Algal Ponds	Moderate	N/I
Waste Stabilisation Ponds	Moderate	N/I

Filters		
Anaerobic Filters	High	N/I
Trickling Filters/Percolating Filter	Moderate to High	Moderate
TERTIARY TREATMENT		
Clarifiers/Plots		
Banks Clarifiers	Moderate	Moderate
Grass Plots/Wetlands	Moderate	Moderate
Package Plant Types		
Enviroflow Biofilter Treatment Plant Systems	High	High
Cromaglass Units	High	High
Land Treatment		
Slow Rate Process	Low to Moderate (dependent on cost of land)	Low to Moderate
Overland Flow Process	Low to Moderate (dependent on cost of land)	Low to Moderate
Rapid Infiltration Treatment Process	Low to Moderate (dependent on cost of land)	Low to Moderate

*N/I – Information not available.

Please note that the costs for treatment are being compared with respect to other systems within these same sections. Meaning costs are low, moderate or high when comparing treatment options with each other in Transfer and Collection Systems and so forth.

Table 8: Wastewater Technologies Matrix

Technology	*Process Types*	*Effluent Quality*	*Water*	*Land*	*O & M**	*Cost*	*Electricity*
COLLECTION AND TRANSFER SYSTEMS							
	Conventional Sewerage	N/I**	Yes	High	High	High – capital High – o & m	Yes
	Simplified Sewerage	N/I	Yes	High	High	Moderate to high Capital Moderate – o & m	Yes
	Vacuum Sewerage	N/I	Yes	High	High	High – capital	Yes
	Settled Sewerage	N/I	Yes	High	High	Moderate to high – Capital Low – o & m	Yes
	Saltwater Flushing/Dual Distribution Systems	N/I	Yes	High	High	High – capital High – o & m	Yes
	Cistern Flush Toilets	N/I	Yes	Low	High	Low to moderate – capital Low to moderate – o & m	No
ONSITE WASTEWATER TREATMENT							
	Pit Latrine	Low	No	Low	Low	Low – capital Low – o & m	No
	VIP Latrine	Low	No	Low	Low	Low – capital Low – o & m	No
	Pour Flush Latrine	Low	Yes	Low	Low	Low – capital Low – o & m	No
	Reed Odourless Earth Closet	Low	No	Low	Low	Moderate – capital	No
	Aqua-privy	Low	Yes	Low	Low	High – capital	No
Composting Toilets	Composting Toilets, Enviroloo	High	No	Low	Low	Low – capital Low – o & m	No
Septic Tank Usage	Septic Tank to Disposal Field	Low	Yes	Low	Low	Low – capital	No
	Septic Tanks leading to Seepage Pits	Moderate	Yes	Low	Low	Moderate – capital	No
	Septic Tanks leading to Wisconsin Mounds.	Moderate	Yes	Moderate	Low	High – capital	No
	Biogas Digester	Low	Yes	Moderate	Low	High – capital	No

Technology	***Process Types***	***Effluent Quality***	***Water***	***Land***	***O & M***	***Cost***	***Electricity***
CENTRALISED AND DECENTRALISED WASTEWATER TREATMENT SYSTEMS							
Primary Treatment							
	Septic Tanks with upflow filter	Moderate	Yes	Low	Low	Moderate – capital	No
	Imhoff Tanks	Low	Yes	Low	Low	Low – capital	No
Ponds/Tanks/Lagoons	Small Anaerobic Ponds treating domestic wastewater	Low	Yes	Moderate	Low	Low to moderate – Capital Low – o & m	No
	High loaded Anaerobic ponds with long HRT	Moderate	Yes	Moderate	Low	Low to moderate – Capital Low – o & m	No
	Low loaded Anaerobic Ponds with short HRT	Low	Yes	Moderate	Low	Low to moderate – Capital Low – o & m	No
	Low loaded Anaerobic Ponds with long HRT	High	Yes	Moderate	Low	Low to moderate – Capital Low – o & m	No
	Low loaded Sedimentation Tanks with short HRT	Low	Yes	Moderate	Low	Low to moderate – Capital Low – o & m	No
	Low loaded Sedimentation Tanks with long HRT	High	Yes	Moderate	Low	Low to moderate – Capital Low – o & m	No
Secondary Treatment							
Reactors	Baffled Septic Tanks	Moderate	Yes	Low	Moderate	Low – capital	No
Activated Sludge Treatment	Activated Sludge Treatment	High	Yes	Low	High	High – capital High – o & m	Yes
Ponds/Beds	Reed Bed System (SSF), Subsurface Flow Wetlands/Root Zone TP/Horizontal Gravel Filter	High	Yes	Moderate	Moderate	Moderate to high – capital	No

Technology	*Process Types*	*Effluent Quality*	*Water*	*Land*	*O & M*	*Cost*	*Electricity*
	Aerobic Stabilisation Ponds/Oxidation Ponds/Algal Ponds	High	Yes	High	Low	Moderate – capital	No
	Waste Stabilisation Ponds	High	Yes	High	Low	Moderate – capital	No
Filters	Anaerobic Filters	Moderate	Yes	Low	High	High – capital	Yes
	Trickling Filters/Percolating Filters	High	Yes	Moderate	High	Moderate to high – capital Moderate – o & m	Yes
Tertiary Treatment							
Clarifiers/Plots	Banks' Clarifiers	High	Yes	High	Low	Moderate – capital Moderate – o & m	No
	Grass Plots/Wetlands	High	Yes	High	Low	Moderate – capital Moderate – o & m	No
Package Plant Types	Enviroflow Biofilter Treatment Plant Systems	High	Yes	Low	High	High – capital High – o & m	Yes
	Cromaglass Units	High	Yes	Low	High	High – capital High o & m	Yes
Land Treatment	Slow Rate Process	Moderate	Yes	High	Low	Low to moderate – capital Low to moderate – o & m	No
	Overland Flow Process	Moderate	Yes	High	Low	Low to moderate – capital Low to moderate – o & m	No
	Rapid Infiltration Treatment Process	High	Yes	High	Low	Low to moderate – capital Low to moderate – o & m	No

*O & M – Operation & Maintenance
**N/I – Information not available.

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7 Glossary

Aerobic	–	living or taking place in the presence of air.
Anaerobic	–	living or taking place in the absence of air or free oxygen.
Biochemical Oxygen Demand (BOD)	–	the mass of oxygen consumed by organic matter during aerobic decomposition. It is always a fraction of COD. It describes what can be oxidised biologically, with the help of bacteria.
Blackwater	–	wastewater containing excreta.
Chemical Oxygen Demand (COD)	–	the most general parameter to measure organic pollution. It describes how much oxygen is required to oxidise all organic and inorganic matter found in water.
Composting	–	the controlled decomposition of organic solid waste in moist conditions to produce a humus.
Desludging	–	removal of settled solids from pits, vaults and tanks.
Excreta	–	human feaces and urine.
Graywater	–	wastewater from bathing, laundry, preparation of food, cooking and other personal and domestic activities that does not contain excreta.
Humus	–	decomposed organic matter.
Hydraulic Retention Time (HRT)	–	indicates a volume by volume relation. It does not for example distinguish between sludge and liquid. The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.
Pathogen	–	disease-causing organism.
Sewage	–	the wastewater usually including excreta carried off by sewers or drains.
Sewer	–	a pipe or drain, usually underground, used to carry off wastewater.
Sewerage	–	removal of surface water and waste matter by sewers. A system of sewers.
Superstructure	–	screen or building of a latrine, above floor level, that provides privacy and protection for users.
Vector	–	insect or other animal that can transmit infection directly or indirectly from one person to another, or from an infected animal to a person.
Water Seal	–	water held in U-shaped pipe or hemispherical bowl connecting a pan to a pipe channel or pit to prevent the escape of gases and insects from the sewer or pit.