Small Scale Wastewater Treatment Plants

Phase 1

Small Scale Wastewater Treatment Plant Project

REPORT ON PROJECT CRITERIA, GUIDELINES AND TECHNOLOGIES

July 1999 **SOPAC Technical Report 288**

The Small Scale Wastewater Treatment Project is funded by NZAID through a cash grant to the South Pacific Applied Geoscience Commission.

[TR288 – Schölzel & Bower]

Table of Contents

1: Introduction

1.1 General

In general, the sanitation field seems to live the life of an orphan in many Pacific Island Countries. In many cases this important sector of public health has been left alone when major upgrading projects improved the water supply systems in many countries and provinces. This basically ignored the downstream effect of improved water supply, that of increased discharges into rivers or aquifers. Two reasons appear to be the major cause for that: firstly, wastewater collection and treatment is costly and their benefit often hard to show; and secondly, even if low-cost solutions are being implemented many projects fail to deliver the expected outcome.

Without pretending to reflect the complexity of sanitation projects three principal reasons may be held accountable for the non-delivery problems:

- The technology was not appropriate,
- The beneficiary was not involved and consulted sufficiently, and
- The responsibilities within government were not resolved to ensure the necessary support.

During the last years many rural areas were provided with some kind of water supply system. The availability of water leads to wider spread use of flush toilet systems. These systems mainly use simple toilets to discard the waste water either directly into the porous underground or into simple holes. At the same time many villages still supplement their water supply from shallow wells which are often located in the direct neighbourhood of the toilets. Even if landowners consider the possible contamination of their well through their own toilet and locate them far apart they can not avoid the location of their neighbour's toilet close to their well. A similar risk of water body contamination occurs where villages situated on the banks of a small estuary/lagoon discharge their wastewater without treatment. It is expected that Small Scale Wastewater Treatment Plants (SSWTP), under certain circumstances, are the solution for these problems. More specifically the SSWTP technology could be applied where,

- conventional sewage is simply too costly,
- environmental conditions require a high effluent quality,
- conventional on-site treatment proved to be of low community acceptance,
- low technology solution, such as composting toilets seem to be inappropriate.

In July 1998 the New Zealand Ministry of Foreign Affairs approved a regional project that aimed at introducing SSWTP into three Pacific Countries. NZ$ 20,000 was allocated to investigate the implications of implementing this important sanitation technology in Fiji, Marshall Islands and Tonga. During the SOPAC 27th Annual Session Niue specially requested to be included in the project.

While it is hard to resolve the problem of government responsibilities for practitioners in the sanitation engineering field, the first and the second problem of non-delivery may be relieved through ensuring certain procedures during project planning and implementation. However, the aim of the SSWTP Project in its first phase is to contribute to technological discussion and provide insight into government structures and procedures within the relevant countries. The method used to achieve this challenging goal was to involve as many experts as possible experts, be they scientists or practitioners, in the early phases of the project. The use of Internet and Email facilities allowed for an extensive technology research and valuable feedback from virtually anywhere in the world. Along with good contacts with government officials at national and district level, project is ensured to reach its addressee during this phase.

1.2 Purpose Of The Project

The main purpose of the project is to identify:

- current wastewater disposal and treatment techniques,
- ongoing sanitation initiatives and projects,
- stakeholders in the sanitation sector,
- the administration structures related to sanitation projects,
- a possible project implementation agency,
- sites for future pilot projects.

2: Acknowledgement

This project is funded by the New Zealand Official Development Assistance through an extra-budgetary cash grant and the German Government through its funding of an United Nations Associate Expert.

Special thanks should be given to the participants of the water and sanitation applied research newsgroup who have provided very valuable information.

3: Scope of the project

Traditionally, sanitation work in developing countries concentrates on research on very rudimentary sanitation facilities such as stand-alone septic tanks, composting toilets or pit toilets. Little is known about the viability of SSWTP. Therefore this project has been designed to provide a comprehensive study to establish guidelines for their application. It is anticipated that on completion of this project, money will be available to implement pilot projects in the participating countries. Consequently the objectives of the project can be summarised as follows:

- To identify appropriate waste water treatment technologies for selected villages in Fiji, Marshall Islands, Niue and Tonga (e.g. treatment by plants, high-loaded treatment lagoons, community septic tanks).
- To identify conditions under which a certain number of toilets can be connected to a single small-scale waste water treatment plant (economic, technical and social viability).
- The formulation by participating countries of specific project proposals for further implementation.

In the context of the project, these objectives mean that the project is **not** necessarily trying to find the best sanitation technology for a given problem but to list the conditions where SSWTP represents an efficient alternative to either conventional sewage or on-site wastewater treatment/disposal technologies. To detail these points is within the scope of the SSWTP project.

As the former point basically refers to technical points the project focuses also on non-technical problems. Here it is anticipated that the planning and implementation framework for sanitation projects will be described in a way that allows the future implementation of such projects.

4: Scope of this report

This report describes technologies the authors believe to be reflecting a fair selection out of the numerous technologies and possible combinations that are available. Experts familiar with the general topic of wastewater treatment or on-site sanitation will understand that this report has to have some 'guidelines' to stay focussed on the South Pacific context.

In order to achieve that, this report gives technical criteria for the selection of wastewater treatment technologies and suggests a rating scheme to find a technology suitable for a particular situation. As with all such rating systems it is unavoidable that some readers may consider the suggested scheme arbitrary. The authors will be happy to discuss any suggestions readers may have.

Since the authors believe that wastewater treatment knowledge is basically non-existent in the South Pacific a general description that summarises the basics of wastewater treatment has been included. It is hoped that this facilitates the 'digestion' of this report.

5: Wastewater Treatment

5.1 Introduction - what is wastewater and what is it made up of?

Human waste or more technically referred to as 'excreta' is defined by Chamber's Concise 20th Century Dictionary as "useless matter discharged by animal alimentary", animals being humans in this context. Excreta is made up of a solid matter, faeces, and a liquid matter, urine and is essentially an organic compound. The constituents making up the compound are carbon, nitrogen, phosphorous, sulphur and hydrogen. Also present are fats, carbohydrates, enzymes, proteins, trace elements, pathogens and many different bacteria.

5.2 Why is it necessary to treat human waste or excreta?

It is necessary to treat human waste or excreta for many reasons, but the most important reason is to preserve health. Untreated human excrement contains a variety of pathogenic organisms, which include protozoa, bacteria, viruses and eggs of helminthes that are disease-causing organisms. The presence of these in the environment transmits various types of diseases. They could be:

- Water borne where pathogens are present in water supplies
- Soil–based where the excreted organism is spread through the soil
- Insect-vector borne where the pathogen is spread by insects that feed or breed in water e.g. flies and mosquitoes.
- Faecal-oral transmission routes by which pathogens from faeces reach the mouth by either hand, clothes food etc.

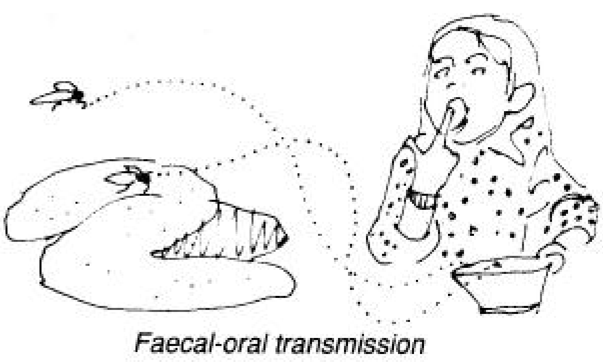


Figure 1: Faecal-oral transmission. Source: Pickford J., 1991

5.3 Deciding which treatment option to use.

Once excrements have been produced, it is necessary to decide what to do with the waste and determine the wastewater treatment option. There is a general distinction : Waste being treated on-site via various treatment options e.g. VIP latrines, water seal toilets, composting toilets etc. or by the use of water to carry the waste off-site to be treated some place else either not too far from the compound as with septic tanks or to specialised treatment plants through sewer lines. This form of waste often is reffered to as wastewater or sewerage.

The total management of wastewater can be separated into four categories:

- wastewater collection,
- wastewater treatment,
- treated wastewater disposal and,
- sludge management.

Waste only becomes non-hazardous to human health after treatment.

5.4 What is Wastewater Treatment?

“The term treatment means separation of solids and stabilisation of pollutants. In turn stabilisation means the degradation of organic matter until the point at which chemical or biological reactions stop. Treatment can also mean the removal of toxic or otherwise dangerous substances (for e.g. heavy metals or phosphorous) which are likely to distort sustainable biological cycles, even after stabilisation of the organic matter.”(Sasse, 1998)

General Parameters to measure organic pollution.

COD (Chemical Oxygen Demand) is said to be the most general parameter to measure organic pollution. COD describes how much oxygen is required to oxidise all organic and inorganic matter found in the wastewater sample. BOD (Biological Oxygen Demand) describes what can be oxidised biologically, with the help of bacteria and is always a fraction of COD. Usually BOD is measured as BOD_5 meaning that it describes the amount of oxygen consumed over a five-day measurement period. It is a direct measurement of the amount of oxygen consumed by organisms removing the organic matter in the waste. SS (Suspended Solids) describes how much of the organic or inorganic matter is not dissolved in water and contains settleable solids that sink to the bottom in a short time and non-settleable suspended solids. It is an important parameter because SS causes turbidity in the water causing clogging of filters etc. The mentioned parameters are measured in 'mg/l'.

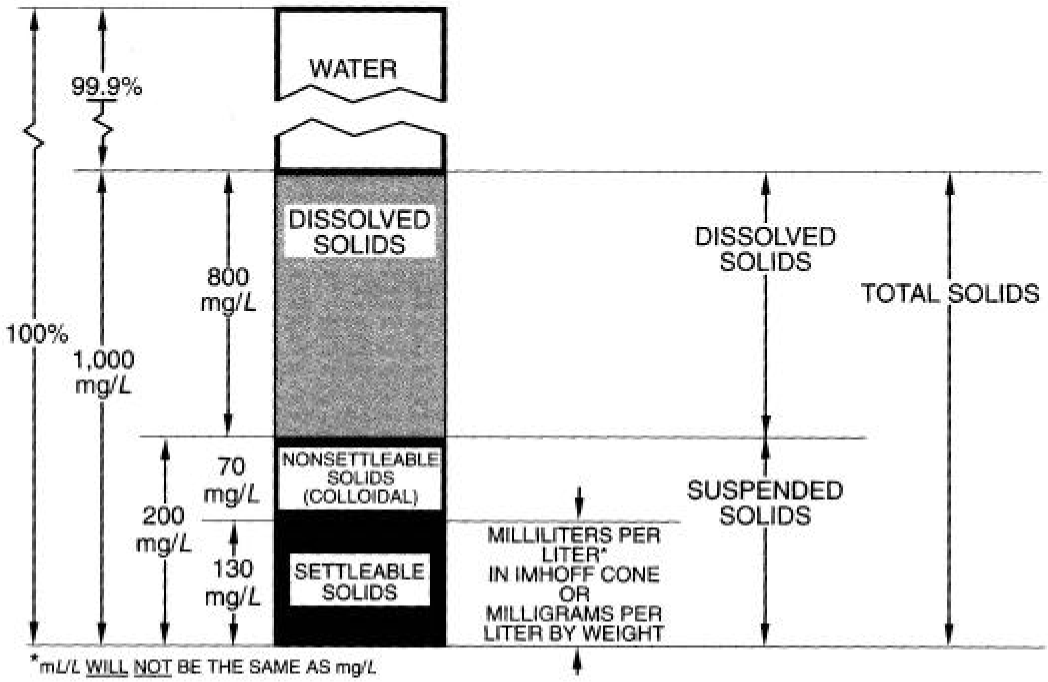


Figure 2 Composition of solids in raw wastewater. Source: Small Wastewater System Operation and Maintenance Vol. 1

5.5 Levels of Wastewater Treatment

Wastewater treatment options may be classified into groups of processes according to the function they perform and their complexity:

Preliminary Treatment – includes simple processes that deal with debris and solid material. The purpose of preliminary treatment is to remove those easily separable components. This is usually performed by screening (usually by bar screens) and grit removal. Their removal is important in order to increase the effectiveness of the later treatment processes and prevent damages to the pipes, pumps and fittings.

Primary Treatment – is mainly the removal of solids by settlement. Simple settlement of the solid material in sewage can reduce the polluting load by significant amounts. It can reduce BOD by up to 40%. Some examples of primary treatment is septic tanks, septic tanks with upflow filters, Imhoff tanks.

Secondary Treatment – In secondary treatment the organic material that remains in the wastewater is reduced biologically. Secondary treatment actually involves harnessing and accelerating the natural process of waste disposal whereby bacteria convert organic matter to stable forms. Both aerobic and anaerobic processes are employed in secondary treatment. Some examples of secondary treatment are UASB, reed bed systems, trickling filters and stabilisation ponds.

Tertiary treatment – is the polishing process whereby treated effluent is further purified to acceptable levels for discharge. It is usually for the removal of specific pollutants e.g. nitrogen or phosphorus or specific industrial pollutants. Tertiary treatment processes are generally specialised processes. Some examples of tertiary treatment are bank's clarifiers, grass plots, etc.

The majority of secondary treatment processes are biological in their nature – i.e. they use the natural activity of the bacteria to break down polluting material. Biological treatment processes can themselves be divided into two general sub-divisions – aerobic and anaerobic processes.

Advanced or quartiairy treatment are applicable only to industrial wastes to remove specific contaminants.

Figure 3 gives an overview on technologies and their categorisation

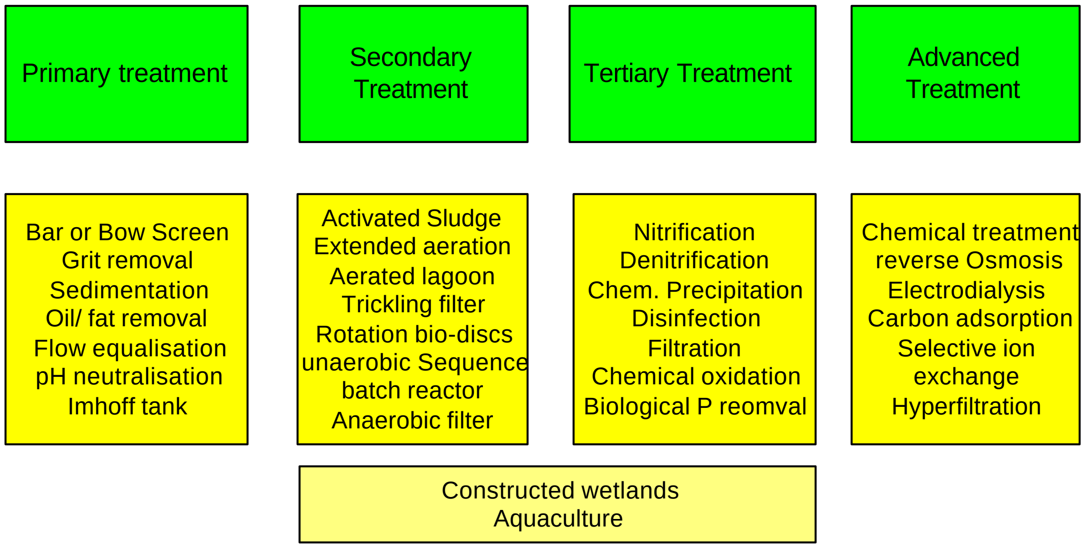


Figure 3: Treatment categorisation and technologies, Source: Veenstra and Alaerts (1996)

5.6 Separation of solids

Wastewater treatment also relies on the separation of solids, both before and after stabilisation. The choice of method of solid removal will depend on the size and specific weight of pieces and particles of suspended solids.

Screening

For the larger pieces of solids for e.g. diapers, cloth, etc. in wastewater treatment. Screens require cleaning at very short intervals. Materials captured through screening require a safe place to be disposed of. Below is a diagram of waste stabilisation ponds showing screening as the first stage.

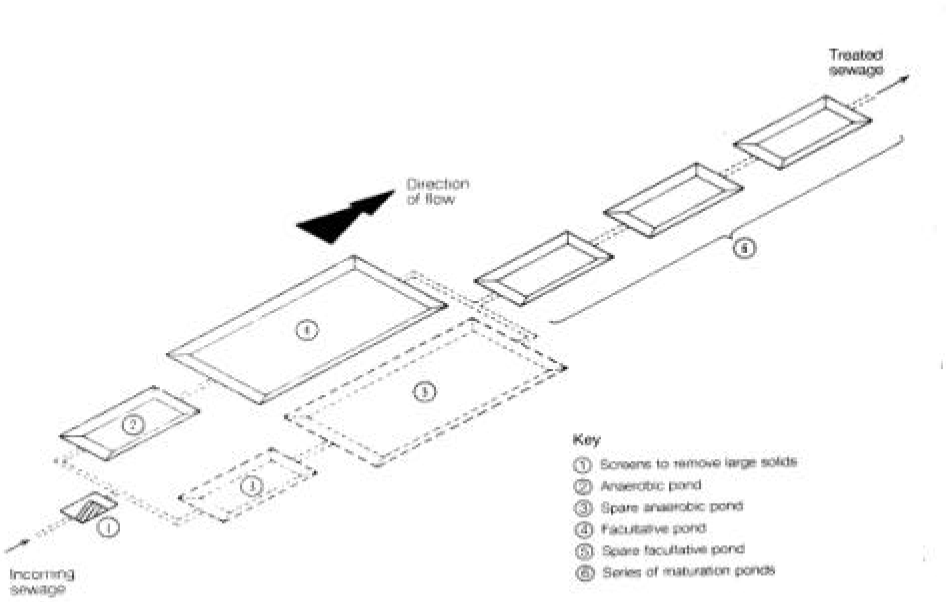


Figure 4: Schematic drawing of a stabilisation ponds system, Source: Pickord J., 1991

Sedimentation

Separation of solids happens primarily by gravity, predominantly through sedimentation. Coarse and heavy particles settle within a few hours or minutes while smaller and lighter particles may need days and weeks to sink to the bottom.

Flotation

Flotation is the predominant method to remove fat, grease and oil. Unwanted flotation occurs in septic tanks and other anaerobic systems where floating layers of scum are easily formed. Accumulated scum could be removed manually or left purposedly to seal the surface of anaerobic ponds to prevent bad odour. Below is a diagram of a septic tank showing scum floating on the surface.

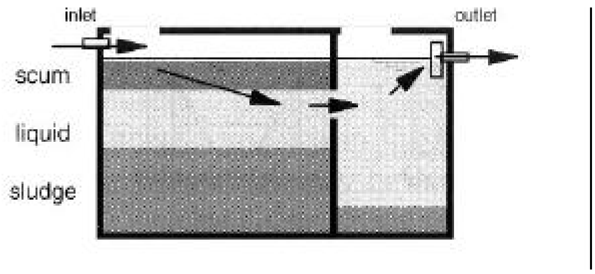


Figure 5: Wastewater separation in a septic tank. Source: Sasse L. 1998

Filtration

Filtration becomes necessary when suspended solid particles are to be removed that cannot be forced to settle or float within a reasonable time. Most filters have a double function, they provide a fixed surface for treatment of bacteria and they form a physical obstacle for the smaller solid particles by creating adhesion of particles to their surfaces. Filtration can be both on the upstream and the downstream. E.g. Upstream Anaerobic Sludge Blanket. Anaerobic filters direct flow upwards through the filter material. Trickling filters allow the wastewater to descend in a downward direction through the filter material. The speed at which filtration occurs depends on the type of filter material used. Smaller grain sizes and fine mesh sizes would cause filtration to be slower than larger, wider-spaced material, but would cause the retention of many more solids and clog faster.

5.7 What are aerobic and anaerobic processes?

With aerobic processes, bacteria use oxygen to feed on the organic material (which is a food source) to produce carbondioxide and water, with the production of quantities of extra bacterial mass (sludge). Most aerobic processes require the mechanical addition of oxygen and that can be expensive.

Anaerobic processes take place in the absence of oxygen and bacteria break down the organic wastes to produce carbondioxide and methane. This mixture of gases, called Biogas, can potentially be harnessed as an energy source. Anaerobic process produces much less excess sludge than aerobic processes however the treatment efficiency is not as high as it is for aerobic processes.

The aerobic process happens much faster than anaerobic digestion and for that reason always dominates when free oxygen is available. The high speed at which decomposition occurs is caused by the shorter reproduction cycles of aerobic bacteria as compared to anaerobic bacteria. Anaerobic bacteria leave some of the energy unused and it is this unused energy which is released in the form of biogas. Aerobic bacteria use a larger portion of the pollution load for production of their own bacterial mass compared to anaerobic bacteria, which is why the aerobic process produces twice as much sludge as the anaerobic process. Aerobic treatment is highly efficient when there is enough oxygen available.

5.8 Sludge accumulation

Sedimentation and particles that escape filtration lead to sludge accumulation at the bottom of vessels. This sludge gets compacted over time, consequently older sludge occupies less volume than fresh sludge. Sludge removal is important and removal should be performed as specified for each technology.

5.9 Elimination of Nitrogen

Nitrogen is a nutrient that causes algal growth in receiving waters and needs to be removed from wastewater before discharge. It is also poisonous to fish in the form of ammonia gases and also may become poisonous in the form of nitrite. The basic process of nitrogen removal occurs in two steps, namely, nitrification (aerobic conditions) followed by denitrification (anaerobic conditions) with the result that pure nitrogen diffuses into the atmosphere. Nitrate is the most stable form of nitrogen and its' presence indicates complete oxidation

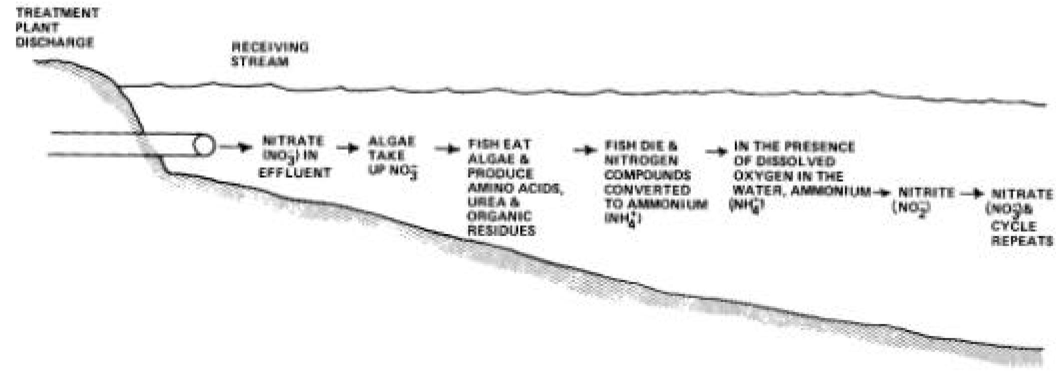


Figure 6: Simplified illustration of Nitrogen cycle. Source: Small Wastewater System Operation and Maintenance Vol. 1

5.10 Elimination of Phosphorus

Phosphorus is a nutrient that is water soluble, often recycled and is required to support living plants and organisms. Bacteria cannot transform phosphorus into a form in which it loses its fertiliser quality permanently. This implies that no appropriate biological process either aerobic or anaerobic can remove phosphorous from wastewater. Phosphorus removal from water normally takes place by removal of bacterial mass (active sludge) or by removal of phosphate fixing solids via sedimentation or flocculation. This process is normally performed in the tertiary stage of treatment.

5.11 Elimination of toxic substances

Most heavy metals are toxic or carcinogenic and therefore should not remain in the wastewater because they harm the aquatic life of the receiving water or could enter the human nutritious cycle when wastewater or sludge is used in agriculture. Since heavy metals settle easy their removal is not difficult however soluble toxic substances may be difficult to remove. There are numerous methods for converting toxins into non-toxic substances for e.g. ion exchange procedures.

5.12 Removal of pathogens

Pathogens are present in many forms in excreta e.g. bacteria, viruses and protozoa and accumulate in the sediment sludge and are largely retained inside the treatment system where they stay alive for several weeks. Most bacteria and viruses caught in the sludge die after shorter periods. Those bacteria, which are not caught in the sludge but remain suspended in the liquid portion, are hardly affected, meaning, these bacteria and viruses exit the plant fully alive. Exposure to UV rays has a substantial hygienic effect. High pathogen removal can also be experienced in shallow ponds with long retention times. Constructed wetlands with their multifunctional bacterial life in the root zones can also be very effective. Using chlorination to kill pathogens is only advisable for hospitals in the case of epidemics and other such special circumstances as chlorine kills all forms of bacteria both beneficial and non-beneficial. Apart from this chlorine has an adverse impact on the environment. Water is made unstable as chlorine itself has a high chemical oxygen demand (COD).

5.13 Conclusion

Wastewater treatment involves a variety of processes performed at different levels of treatment. The basic form of treatment is the breaking down of organic waste by bacteria either aerobically or anaerobically or a combination of both which occurs in secondary treatment. Primary treatment offers the settlement of solids. Tertiary treatment involves the removal of phosphorus, nitrogen and toxic substances. Pathogen removal occurs throughout treatment but becomes more effective mostly at tertiary levels through the use of UV rays and chlorination. The higher the treatment efficiency the better the quality of effluent produced.

6: SMALL-SCALE WASTEWATER TREATMENT PLANTS CRITERIA EVALUATION

6.1 Introduction:

The preliminary criteria of the small-scale wastewater project, given its objectives, was determined by careful consideration of what was important when making wastewater technological choices. Criteria were then prioritised, after which a table was set up rating each technology against these criteria for better evaluation.

6.2 General Assumptions

General assumptions need to be made to keep a clear focus on the project objectives. If these assumptions were not made then the choice of technology would be restricted to a selected few. The assumption is that there is enough sustainable water supply for the use of waste disposal

6.3 Effluent Quality

The technology chosen should produce effluent quality that is up to standard with regards to the various quality measurements: BOD, suspended solids, nitrogen, phosphates etc. Different technologies provide different levels of waste treatment, removing contaminants by various methods. All options must be carefully considered with respect to the treatment quality that is provided for by the different technologies. This is an important criterion and is the determining factor in the effectiveness of the different technologies chosen

In terms of effluent quality produced the ratings are as follows:

Low Effluent Quality, Moderate Effluent Quality, High Effluent Quality

6.4 Water Supply

Water is used in waste disposal mainly for the transportation of sewage from one place to the next although it is used in the biological degradation of organic matter to a certain degree as well. The assumption made by us is that there is enough water supplied for this use as well as sustained for continuing future use for either purpose. Water is placed here in the criteria because it is a key aspect in differentiating technologies. Without water, it would be difficult to transport the sewerage to another site to be treated. This allows only one option for on-site treatment, by the use of composting toilets. Locations that are not capable of providing this water requirement would then be limited to on-site treatment options.

To sustain water supply, a moderate amount must be used for this.

The water supply ratings are as follows:

Water Supply: Yes

Water Supply: No

6.5 Land Space

The reason for a limited land space requirement is that land issues are always a problem and must be handled carefully. In a village, land may be owned by many families each claiming their own piece. This family ownership does not only include the immediate family, but encompasses the extended family as well, resulting in many people owning a piece of land. Land secured for waste treatment would be difficult to obtain. This is also placed high on the list because often there is limited land available and this needs to be taken into account when choosing a technology. Although this would restrict our options, limited land availability most often can't be overcome.

In terms of land space the ratings are as follows:

Low land requirement, moderate land requirement, high land requirement

6.6 Maintenance and Operation

It is assumed that a certain degree of maintenance is required and also a skilled workforce to perform maintenance and operational duties when needed. The maintenance of a wastewater treatment system is then left up to the villagers themselves after implementation where it is assumed that at least one villager has the capability to oversee the operation and maintenance of the system. Although the operation and maintenance of the system may be reviewed from time to time by the relevant parties it is most often left to the villagers themselves in the long run. The proper maintenance of the chosen system would be a limiting factor in terms of the sustainability of the project at the village level, as it has been seen from past experiences that most often maintenance has not been satisfactory. To overcome this, proper maintenance and operation training should be made available to certain people who are responsible for this duty. Sometimes mechanical equipment is imported and when parts need repair or replacement they are not available locally so the system becomes non-operational for a period of time.

This criteria is placed here because maintenance and operation are important and need to be considered when making a technological choice because the sustainability of chosen technology rely on the proper workings of the two. Some skill would be required for any technology, choice made as there is no technology that does not require maintenance at all. Choices should perhaps be directed towards relatively low maintenance systems.

In terms of maintenance and operation the ratings are as follows:

Low O & M, Moderate O & M, and High O & M

6.7 Cost

Financial support may be supplied by many sources. On a village level, funding may be provided by the villagers themselves with the assistance of local government departments e.g. Department of Health etc. Apart from this, financial service may also be provided from other sources like foreign aid programs and so forth. Initially there would be cost of construction after which the running costs may come into effect e.g. cost of maintenance etc.Cost is not to be placed first on the list because within the scope of this project it should not be the determining factor in the type of treatment system chosen. However, people sometimes take the option of a less-than-adequate system that does not perform satisfactorily giving out poor quality effluent for the sake of cutting costs. The financial resources of the local area under consideration may not be much, but there may often be foreign donor support for well-presented projects etc.

In terms of the ratings are:

Low Cost , Medium Cost, High Cost

6.8 Electrical requirement:

Electrical power may be used in many different ways in the waste treatment system for e.g. it may be used for pumps to transport the sewerage from one place to the next and also may be used in technologies involving aeration etc. Those technologies that are dependent on electrical power for operation can sometimes become non-operational due to power cuts. The assumption made is that the requirement of electrical power for operation is not essential because there are technologies that can be chosen which do not need electricity to operate. If electricity can be provided this just broadens the options of technological choices.

This criteria is not placed high on the list as there are technological options available that don't require electricity and it is often not essential in the choices made. It is included in the list of criteria because often the use of package plant type options requires electrical power for operation.

The ratings for electrical requirement are:

Electrical Requirement – Yes

Electrical Requirement – No

6.9 Topography

Topographic conditions e.g. the slope of an area etc. have an influence over the type of technology chosen and these conditions change from one site to the next. Some areas have a topography that allows easier implementation of wastewater technologies then others. The types of wastewater technologies chosen with consideration of topographic conditions work more efficiently as with these technical considerations in mind they become more effective, producing better quality effluent. Topographic conditions should be considered as a criterion however is not included in the rating sheet as it is very site specific.

6.10 Technology Rating Sheet

Technology		**Criteria**					
PROCESS TYPES		Effluent Quality	Water	Land	O&M	Cost	Electricity
(Primary Treatment)							
Composting Toilets	Composting Toilets, Enviroloo, Soltran II.	Low	No	Low	Low	Low	No
Composting Toilets	Composting Toilets, Nature-Loo, Rota-Loo, Biolet	Low	No	Low	Low	Low	Yes
Septic Tank Usage	Septic Tank to disposal field	Low	Yes	Low	Low	Low	No
	Septic Tank with up-flow filter	Moderate	Yes	Low	Low	Moderate	No
	Imhoff Tanks	Low	Yes	Low	Low	Low	No
Ponds/Lagoons/Tanks	Small Anaerobic Ponds treating domestic wastewater	Low	Yes	Moderate	Low	Moderate	No
	High loaded Anaerobic Ponds with long HRT	Moderate	Yes	Moderate	Low	Moderate	No
	Low loaded Anaerobic Ponds with short HRT	Low	Yes	Moderate	Low	Moderate	No
	Low loaded Anaerobic Ponds with long HRT	High	Yes	Moderate	Low	Moderate	No
	Low loaded Sedimentation Tanks short HRT	Low	Yes	Moderate	Low	Moderate	No
	Low loaded Sedimentation Tanks with long HRT	High	Yes	Moderate	Low	Moderate	No
Secondary Treatment							
Activated Sludge	UASB Upflow Anaerobic Sludge Blanket	Moderate	Yes	Low	Moderate	Low	No
Septic Tanks	Baffled Septic Tanks	Moderate	Yes	Low	Moderate	Low	No
Land Treatment	Slow Rate Process	Moderate	Yes	High	Low	Moderate	No

Technology		**Criteria**					
PROCESS TYPES		Effluent Quality	Water	Land	O&M	Cost	Electricity
	Overland Flow Process	Moderate	Yes	High	Low	Moderate	No
	Rapid Infiltration Treatment Process	High	Yes	High	Low	Moderate	No
Ponds/Beds	Reed Bed System/(SSF) Subsurface Flow Wetlands/Root Zone TP/Horizontal Gravel Filter	High	Yes	Moderate	Moderate	Moderate	No
	Aerobic Stabilisation Ponds/Oxidation Ponds/Algal Ponds	High	Yes	High	Low	Moderate	No
Ponds/ Lagoons	Waste Stabilisation Ponds	High	Yes	High	Low	Moderate	No
Filters	Anaerobic Filters	Moderate	Yes	Low	High	High	Yes
	Trickling Filters/Percolating Filter	High	Yes	Moderate	High	High	Yes
Activated Sludge	Activated Sludge Treatment	High	Yes	Low	High	High	Yes
Tertiary Treatment							
Hybrid Systems	Hybrid Toilet Systems (HTS)	High	No	Low	Moderate	Moderate	Yes
Package Plant Types	N-DN Biofilter Treatment Plants	High	Yes	Low	High	High	Yes
Package Plant Types	Enviroflow Biofilter Treatment Plant System	High	Yes	Low	High	High	Yes
Package Plant Types	Cromaglass Unit	High	Yes	Low	High	High	Yes
Package Plant Types	Intermittent Decanted Extended Aeration System. (IDEA)	High	Yes	Low	High	High	Yes
	Tertiary Lagoons	High	Yes	High	Low	Moderate	No
	Banks' Clarifiers	High	Yes	High	Low	Moderate	No

Technology		**Criteria**					
PROCESS TYPES		Effluent Quality	Water	Land	O&M	Cost	Electricity
	Grass Plots	High	Yes	High	Low	Moderate	No

6.11 Conclusion

The table ratings were done from the available information. It can be seen from the different ratings that each technology has its strong and weak points and therefore an effective combination of these treatment technologies together would maximise treatment options.

Due to the fact that not all information is presented in the table a conclusive result cannot be made to totally represent all technologies present.

7: Small-Scale Technologies

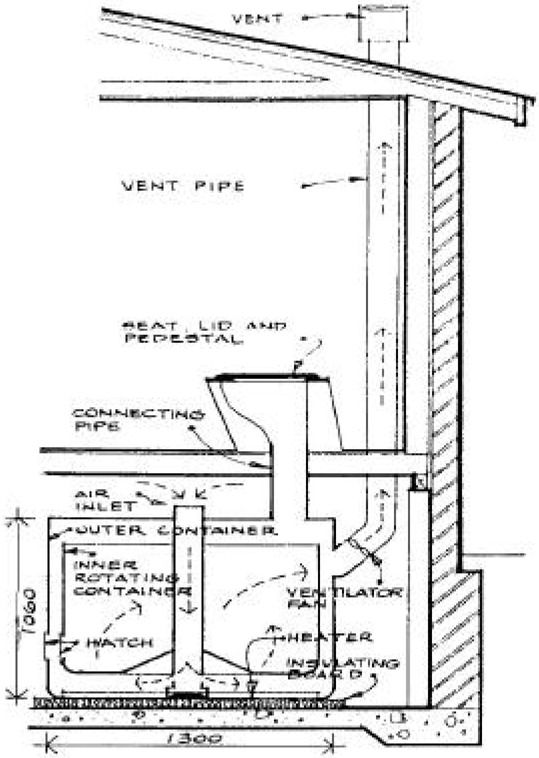
7.1 General

The following pages provide an overview of the identified small-scale wastewater treatment technologies. The list does not claim to be complete but comprehensive. The outline follows the complexity of the different systems as well as the effluent quality that can be achieved by the respective treatment technology.

The sheets do not contain designing criteria. A separate software will be designed and distributed once this report has been approved by the NZODA and the participating Pacific Island Countries.

7.2 Identified technologies

7.2.1 Primary Processes

Primary Process	**Treatment Information**
Composting Toilets  *Source: Rotaloo Composting Toilets, Environment Equipment Rotaloo Brochure.*	There are many different types of composting toilets on the market today namely, Natureloo, Carousel composting toilet, Enviro Loo, Soltran II, Rotaloo, Biolet. Other types of composting toilet systems are prevalent which have been designed by consultants using local materials. All these toilets have utilised the idea of composting to treat wastes and have in their different ways made modifications to their products. Composting is a natural process through which organic material is decomposed and returned to the soil which are then acted upon by organisms in the soil producing a valuable soil conditioner (humus). In a composting toilet, water is not used at all and human waste and other organic material (dried leaves) are deposited into a digestion chamber where solid portions are decomposed by Aerobic bacteria and liquids are left to evaporate through a specially designed ventilation system. Digestion chambers will take a certain period of time to fill up depending on the particular system and finished compost can be cautiously removed avoiding contact with hands and can be buried in a shallow hole or trenched around roots of trees.

GENERAL INFORMATION

O & M

- Simple construction
- Requires manual removal and disposal of finished composting material after a period of time.
- Need to keep toilet lid closed when not in use
- Some composting toilet systems require the addition of bulking material (wood chips, dried leaves, coconut husks etc.) e.g. Soltran II to assist with the composting process while other systems don't e.g. Enviroloo.

Some composting toilet systems do not require electricity however a few systems do to power ventilation fans.
Low land requirement
Does not require water for use.
Finished Compost can still be contaminated with pathogens and should always be handled with care.

ADVANTAGES	**DISADVANTAGES**
• Low land space requirement • No electrical requirements • Low operational and maintenance requirements • No water required	• Finished compost still contaminated with pathogens • Low cost • Problems with acceptability

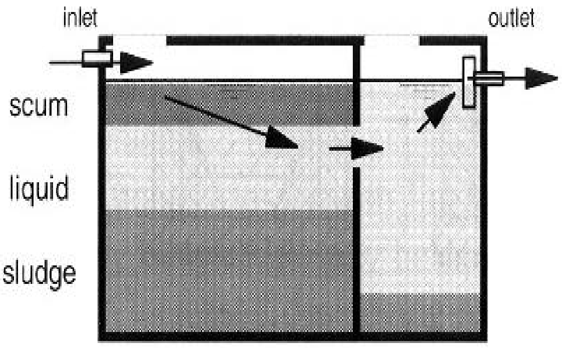
Important Sources of Information –

Del Porto, D. The Soltran II Non-Polluting Biological Toilet and Wastewater Garden
Environment Equipment, Rotaloo Composting Toilet Brochure
Environment Equipment, Biolet Composting Toilet Brochure

<table>
<tr><th>PRIMARY PROCESS</th><th>TREATMENT INFORMATION</th></tr>
<tr><td>

Septic Tank

Septic Tank, Longitudinal Section



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

</td><td>

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

</td></tr>
</table>

General Information

Effluent Quality

- This is rough primary treatment prior to secondary or tertiary treatment
- 25-50% COD removal
- 40% BOD reduction of raw sewage
- 65% Suspended Solids reduction
- Effluent still contains pathogenic bacteria, cysts and worm eggs.

Water Information

- Both greywater and blackwater can be flushed through the system
- Since only accepts liquid waste must be connected to a flush toilet. Not suitable where water supply scarce or unreliable.

O&M

- Construction of septic tank requires skilled labour
- Little maintenance however requires regular desludging.

No electrical requirement.
Low land requirement

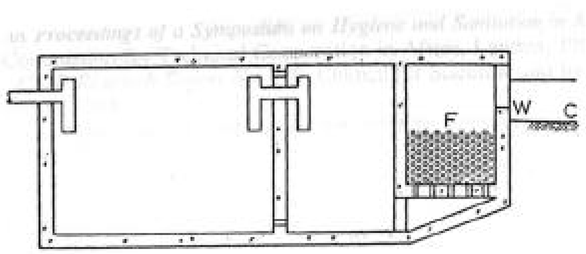
Advantages	Disadvantages
• Low cost • Low land space required • No electrical requirements • Low operational and maintenance requirements • Construction material locally available	• Low effluent quality. • Still heavily contaminated with pathogens, cysts and worm eggs.

Important Sources of Information –

Sasse, L. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries
Mara, D. Sewage Treatment in Hot Climates
Loetscher T., 1998. SANEX Sanitation Expert System
s

Primary Process	Treatment Information
Septic Tank	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.

Septic Tank With Upflow Filter
Longitudinal Section



F – Filter, W – Effluent Weir,
C – Effluent Channel

Source: Septic tank with upflow filter after Mara, D

GENERAL INFORMATION

Effluent quality:

- Can affect 70% reduction in BOD
- Changes a malodorous highly turbid, grey to yellow influent to an odourless clear light yellow effluent.

Water Information

- Both greywater and blackwater can be flushed through the system.
- Since they only accept liquid waste must be connected to a flush toilet. Not suitable where water supply scarce or unreliable.

O & M

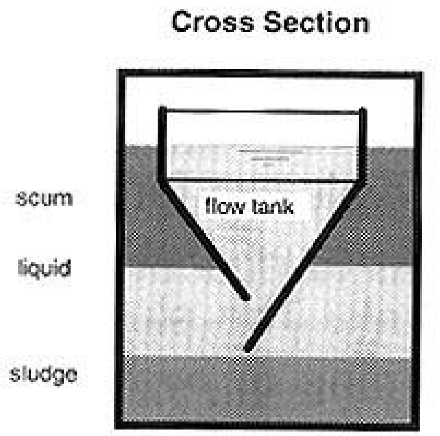
- Construction of septic tank and upflow filter requires skilled labor
- Filter may be expected to operate without maintenance for 18-24 months. Need to then drain filter and wash it with freshwater.
- Septic tank needs regular desludging. Filter and the septic tank can be cleaned together.

No electrical requirement
Low land requirement

ADVANTAGES	DISADVANTAGES
• Low cost and low land space required • No electrical requirements • Low operational and maintenance requirements • Construction material locally available	• Needs skilled construction

Important Sources of Information –

Mara, D. Sewage Treatment in Hot Climates

PRIMARY PROCESS	TREATMENT INFORMATION
Imhoff Tanks Imhoff Tank  *Source: Flow Principle of the Imhoff Tank after Ludwig, S. 1998*	Imhoff tanks are used for domestic or mixed wastewater flows where effluent will undergo further treatment on ground surface. The Imhoff tank is divided into an upper settling compartment in which sedimentation of solids occurs. Sludge then falls through opening at the bottom into the lower tank where it is digested anaerobically. Methane gas is produced in the process and is prevented from disturbing the settling process by being deflected by baffles into the gas vent channels. Effluent is odourless because the suspended and dissolved solids in the effluent do not come into contact with the active sludge causing it to become foul. When sludge is removed needs to be further treated in drying beds or such for pathogen control

GENERAL INFORMATION

Effluent quality:

- Treatment efficiency equivalent to primary treatment.
- 40% BOD reduction
- 65% Suspended solids reduction
- Poor pathogen removal Effluent still contaminated with pathogens.

Water Information

- Since they only accept liquid waste must be connected to a flush toilet. Not suitable where water supply scarce or unreliable.
- Both greywater and blackwater can be flushed through the system

O & M

- Construction of Imhoff tanks requires skilled labor
- Require removal of scum and sludge at regular intervals.
- Apart from desludging and removal of scum no significant maintenance required.

No electrical requirement
Low land requirement

ADVANTAGES	DISADVANTAGES
• Low cost • Low land space required • No electrical requirements • Low operational and maintenance requirements • Construction material locally available	• Needs skilled contractors for construction • Poor effluent quality. Effluent still contaminated with pathogens

Important Sources of Information –

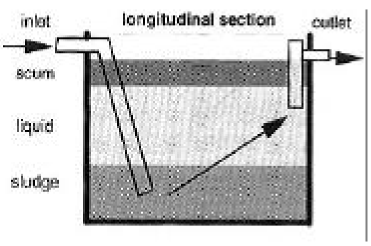
Sasse, L, 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries
Loetscher,T. 1998. SANEX Sanitation Expert Systems

PRIMARY PROCESS	**TREATMENT INFORMATION**

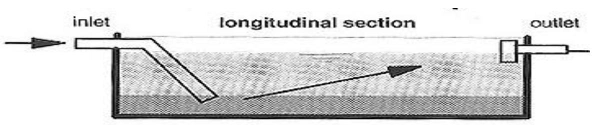
Ponds/Tanks

Anaerobic Ponds

High Loaded Anaerobic Pond



Low Loaded Anaerobic pond



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

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

GENERAL INFORMATION

<u>Effluent quality:</u>

- Treatment efficiency of small ponds treating domestic wastewater 50-70% BOD removal
- Treatment efficiency of 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

<u>Water Information</u>

- Both greywater and blackwater can be flushed through the system

<u>O & M</u>

- 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.

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.

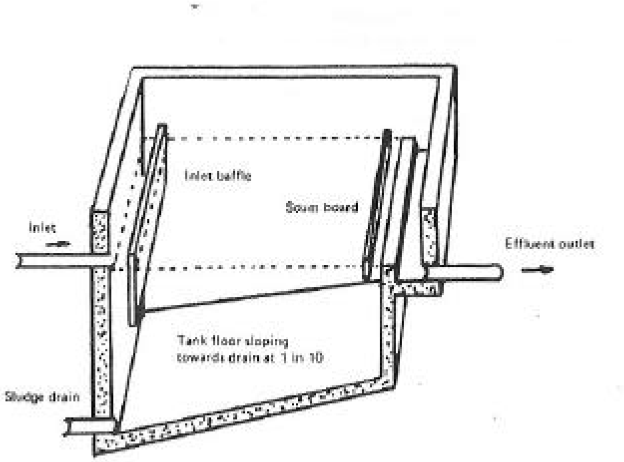
No electrical requirement

Moderate Costs

ADVANTAGES	**DISADVANTAGES**
• No electrical requirements • Low operational and maintenance requirements • Construction material locally available • High effluent quality for low loaded ponds with long HRT	• Poor effluent quality for low loaded ponds with short HRT or domestic water. • Low effluent quality for small ponds treating domestic wastewater

Important Sources of Information –

Sasse, L. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries
Mann, H.T., Williamson, D., 1982. Water Treatment and Sanitation

PRIMARY PROCESS	TREATMENT INFORMATION
Ponds/Tanks Sedimentation Tanks  *Source: Horizontal Flow Type after Mann, H.T.,Williamson,D., 1982*	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.

GENERAL INFORMATION

Effluent quality:

- Treatment Efficiency of low loaded tanks with short Hydraulic Retention Times 57% BOD removal, 53% COD removal
- Treatment efficiency of low loaded tanks with long Hydraulic Retention Times 98% BOD removal, 96% COD removal

Water Information

- Both greywater and blackwater can be flushed through the system
- Since they only accept liquid waste must be connected to a flush toilet. Not suitable where water supply scarce or unreliable.
- Requires high volumes of water for transportation to treatment site.

O & M

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

No electrical requirement
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.
Moderate Costs

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

Important Sources of Information –

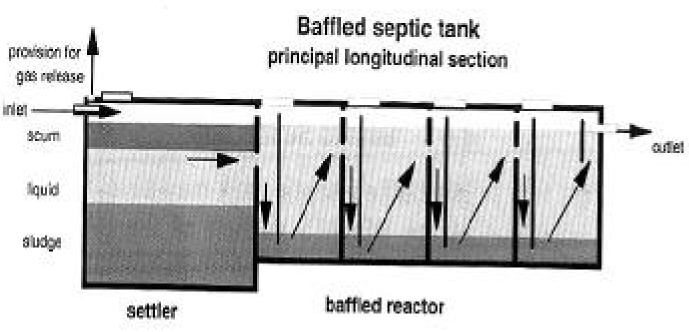
Sasse, L. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries
Mann, H.T., Williamson, D., 1982. Water Treatment and Sanitation

7.2.2 Secondary Processes

<table>
<tr><th>SECONDARY PROCESS</th><th>TREATMENT INFORMATION</th></tr>
<tr><td>

Reactors

Baffled Septic Tanks



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

</td><td>

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 influent 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.

</td></tr>
<tr><td colspan="2">

GENERAL INFORMATION

<u>Effluent quality:</u>

- Treatment Efficiency 70-95% BOD removal, 65-95% COD removal.
- Moderate Effluent Quality

<u>Water Information</u>

- Both greywater and blackwater can be flushed through the system
- Since they only accept liquid waste must be connected to a flush toilet. Not suitable where water supply scarce or unreliable.

<u>O & M</u>

- Requires skilled labor for construction.
- Sludge removal is important and must be done regularly
- Flow regulation is also important as up-flow velocity should not exceed 2m/h.
- Moderate operation and maintenance requirements

No electrical requirement
Low land requirement

</td></tr>
<tr><th>ADVANTAGES</th><th>DISADVANTAGES</th></tr>
<tr><td>

- Low cost
- No electrical requirements
- Construction material locally available
- Low land space required

</td><td>

- Needs skilled contractors for construction

</td></tr>
<tr><td colspan="2">

Important Sources of Information –

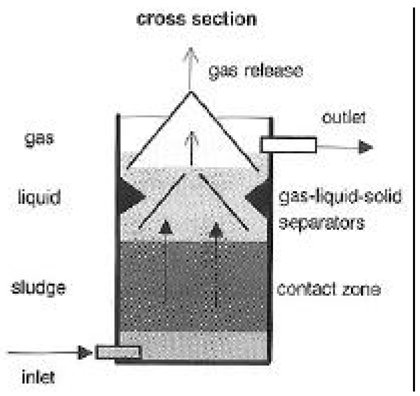
Sasse, L. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries

</td></tr>
</table>

SECONDARY PROCESS

Activated Sludge Treatment

Upstream Anaerobic Sludge Blanket
UASB



Source: Flow Principle of UASB Reactors after Sasse, L. 1998

TREATMENT INFORMATION

This process is suitable for all kinds of wastewater including domestic. The UASB maintains a cushion of active sludge suspended on the lower part of the digestor and uses this sludge blanket directly as filter medium. The sludge blanket is kept in place by the equilibrium formed between the upstream velocity and settling speed of the sludge. After weeks of maturation, granular sludge forms which improves the stability and filter capacity of the sludge blanket. The organic load of the system is responsible for the development of new sludge. A fully controlled UASB is used for relatively strong industrial wastewaters where biogas can be utilised, with slanting baffles separating gas bubbles from solids. UASB require several months to mature i.e. to develop sufficient granular sludge for treatment.

GENERAL INFORMATION

Water Information

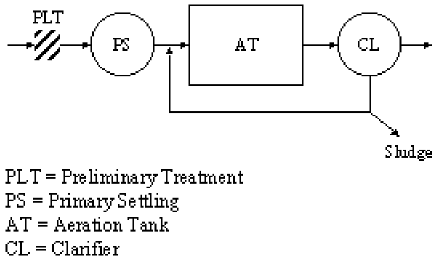
- Both greywater and blackwater can be flushed through the system
- Since they only accept liquid waste must be connected to a flush toilet. Not suitable where water supply scarce or unreliable.

Low land requirement
Moderate operation and maintenance required

ADVANTAGES	DISADVANTAGES
• Low cost • Low land space required	• Needs time to stabilise process • Requires operator intervention from time to time to control and adjust treatment process

Important Sources of Information –

Sasse, L., 1998. DEW ATS Decentralised Wastewater Treatment in Developing Countries

SECONDARY PROCESS	TREATMENT INFORMATION
Activated Sludge Treatment Activated Sludge Treatment  *Source: After Loetscher T., 1998*	Activated sludge treatment is a train of processes designed to treat wastewater collected from a sewer network. The preliminary treatment removes coarse solids and grease and primary settling allows further removal of solids. It is in the Aeration tank that micro-organisms use oxygen to breakdown organic pollutants. Flocs are formed which settle in clarifier forming a sludge layer that is then disposed in drying beds etc. at a sludge disposal site. The clear liquid left in the clarifier can either be further treated or discharged. Suitable for blackwater as well as greywater.

GENERAL INFORMATION

Effluent quality:

- Treatment efficiency 95% BOD removed
- 90% Suspended Solids removed

Water Information

- Since they only accept liquid waste must be connected to a flush toilet. Not suitable where water supply scarce or unreliable.
- Requires high volumes of water for transportation to treatment site.
- Both greywater and blackwater can be flushed through the system

O & M

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

Use of pumps and control equipment needs electrical energy.
Low land requirement

ADVANTAGES	DISADVANTAGES
• Low land requirement • High Effluent quality.	• Needs skilled contractors for construction • Importation of some construction material • Needs trained operator • High cost. • Requires electricity • High operation and maintenance

Important Sources of Information –

Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan
Loetscher T., 1998. SANEX Sanitation Expert Systems

SECONDARY PROCESS	TREATMENT INFORMATION
Land Treatment Slow Rate Process (No Diagram Available)	The processes of land treatment are selected mainly on the basis of soil permeability of the treatment site. Prior to land treatment there needs to be preliminary treatment through either screening, grit removal or primary sedimentation to reduce soil clogging and to prevent nuisance conditions from occurring. Slow rate process requires a soil permeability of 5 to 50mm/hr and a depth of a minimum of 1m to groundwater. It should be in a site with a clay loam to sandy loam soil type with a slope of less than 15% for cultivated land and less than 40% for forested land. Disposal of effluent can be through evapotranspiration and percolation. There is a need for vegetation with Slow Rate Process.

GENERAL INFORMATION

Effluent quality:

- No information available

Water Requirement

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

High land requirement
Low operation and maintenance required.
No electrical requirement
Moderate costs

ADVANTAGES	DISADVANTAGES
• Low operation and maintenance • No electrical requirement • Construction material locally available	• High land space required

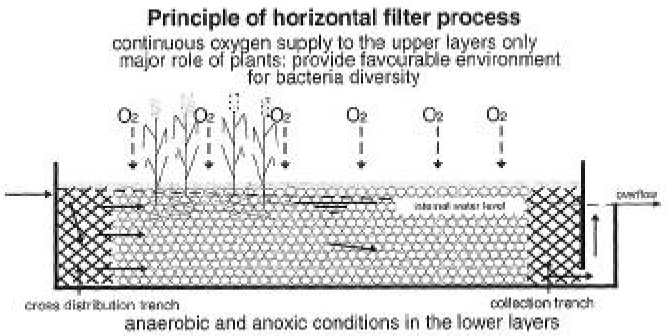
Important Sources of Information –

Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan

<table>
<tr><td>SECONDARY PROCESS</td><td>TREATMENT INFORMATION</td></tr>
<tr><td>Land Treatment
Overland Flow Process
(No Diagram Available)</td><td>This is also a land treatment process and requires preliminary treatment of grit screening etc. In overland flow process the soil permeability should be less than 5mm/hr. The depth to groundwater is not critical and the soil type should be either clay, silts and soils with impermeable barriers, the slope of the area being between 1-8%. Surface runoff and evaporation with some percolation can dispose of the effluent. There is a need for vegetation in overland flow process.</td></tr>
<tr><td colspan="2">GENERAL INFORMATION
<u>Effluent quality:</u>
• No information available
<u>Water Requirement</u>
• Since receive liquid waste not suitable where water scarce or unreliable.
• Requires high volumes of water for transportation to treatment site

High land requirement
Low operation and maintenance required.
No electrical requirement.
Moderate Costs</td></tr>
<tr><td>ADVANTAGES</td><td>DISADVANTAGES</td></tr>
<tr><td>• Low operation and maintenance
• No electrical requirement
• Construction material locally available</td><td>• High land space required</td></tr>
<tr><td colspan="2">Important Sources of Information –
Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan</td></tr>
</table>

<table>
<tr><td>SECONDARY PROCESS</td><td>TREATMENT INFORMATION</td></tr>
<tr><td>Land Treatment
Rapid Infiltration Treatment Process
(No diagram available)</td><td>Rapid Infiltration Land Treatment process also needs to also be preceded by preliminary treatment in order to reduce soil clogging and prevent nuisance conditions from occurring. This treatment process can only be used in soils having a permeability of greater than 50mm/hr. The depth to groundwater should be a minimum of 3m in sandy or sandy loam soil types. The disposal of effluent can be done mainly through percolation.</td></tr>
<tr><td colspan="2">GENERAL INFORMATION
<u>Effluent quality:</u>
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
<u>Water Requirement</u>
Since only receive liquid waste not suitable where water scarce or unreliable.
Requires high volumes of water for transportation to treatment site
High land requirement
Low operation and maintenance required.
No electrical requirement.
Moderate Costs</td></tr>
<tr><td>ADVANTAGES</td><td>DISADVANTAGES</td></tr>
<tr><td>Low operation and maintenance
No electrical requirement
Construction material locally available.
High effluent quality</td><td>High land requirement</td></tr>
<tr><td colspan="2">Important Sources of Information –
Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan</td></tr>
</table>

SECONDARY PROCESS	TREATMENT INFORMATION
Ponds/Beds/Lagoons Reed Bed System/(SSF) Subsurface Flow /Wetlands/Root Zone Treatment Plants/Horizontal Gravel Filter Horizontal Gravel Filter  *Source: Principle of the Horizontal Filter after Ludwig, S. 1998*	Reed bed systems are suitable for domestic and industrial wastewater that has undergone preliminary treatment and that has a COD content not higher than 500mg/l. The reed bed system is 1m deep basin sealed with clay or some other form of lining to prevent percolation into groundwater with the basin itself being filled with soil in which reeds are then planted. Oxygen is transported through the pores of the plant down to the roots whereby the oxygen content increases the biological activity of the soil. When wastewater runs through the root zone soil organic compounds and other impurities are eliminated by micro-organisms in the soil.

GENERAL INFORMATION

Effluent quality:

- 84% COD removal rates
- 86% BOD removal rate

Water Information

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

O & M

- Low operation and maintenance required.
- Regular maintenance of erosion trenches

No electrical requirement.
Moderate land requirement
Moderate Costs

ADVANTAGES	DISADVANTAGES
• Low operation and maintenance • No electrical requirement • Construction material locally available. • High effluent quality	

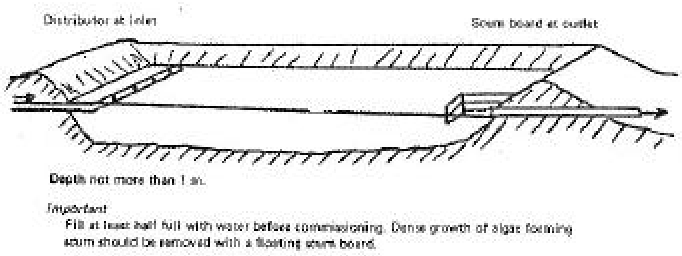
Important Sources of Information –

Sasse, L. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries
Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan

<table>
<tr><th>SECONDARY PROCESS</th><th>TREATMENT INFORMATION</th></tr>
<tr><td>

Ponds/Beds/ Lagoons

Aerobic Stabilisation Ponds/Algal Ponds/Oxidation Ponds



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

</td><td>

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.

</td></tr>
</table>

GENERAL INFORMATION

Effluent quality:

- 82% BOD removal rates
- Upto 97% BOD removal rates in multiple pond systems
- 78% COD removal rates
- pathogen removal 95%

Water Requirement

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

O & M

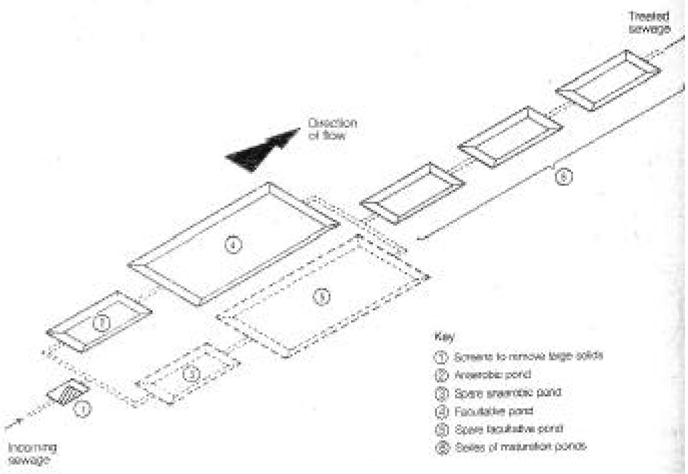
- Low operation and maintenance required
- Regular desludging in defined intervals and start up needs special arrangement.

No electrical requirement
Moderate land requirement, although if aeration provided land required even less.
Moderate Costs

ADVANTAGES	DISADVANTAGES
• Low operation and maintenance • No electrical requirement • Construction material locally available. • High Effluent quality	

Important Sources of Information –

Sasse, L. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries
Mann,H.T., Williamson, D., 1982. Water Treatment and Sanitation

SECONDARY PROCESS	TREATMENT INFORMATION
Ponds/Beds/Lagoons Waste Stabilisation Ponds  *Source: After Pickford, J., 1991*	Waste stabilization ponds are 3 or more, large, shallow, man-made lakes or ponds in a sequence designed to treat wastewater collected from either a sewer network or from small bore sewers etc. Simply sewage which has been screened to remove large solids enters a system of ponds the first being the anaerobic pond which receives the raw sewage. Some wastes float to the surface as scum which then prevents the pond from being aerated by wind and turning aerobic. Other wastes sink to the bottom as sludge where they are digested by anaerobic bacteria. Effluent then enters the facultative pond that has an aerobic zone close to pond surface and a deeper anaerobic zone. Pathogen removal occurs in the last maturation pond, which is an aerobic pond whereby oxygen is transferred to water by wind and algae. Warm temperatures accelerate the treatment of wastes.

GENERAL INFORMATION

Effluent quality:

- Produce very clear effluent equivalent to activated sludge treatment.
- 95% BOD removal
- 90% Suspended Solids removal

Water Requirement

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

O & M

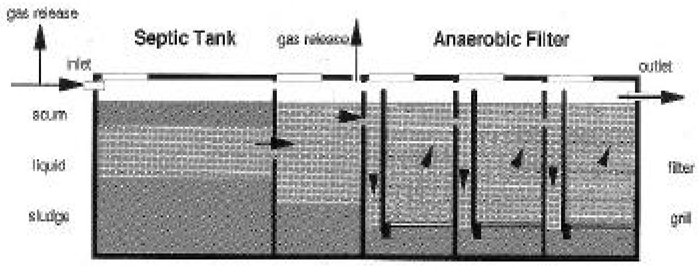
- Low operation and maintenance required
- Grass around ponds need to cut regularly.
- Regular desludging is required

No electrical requirement.
High Land requirement
Moderate Costs

ADVANTAGES	DISADVANTAGES
• Low operation and maintenance • No electrical requirement • Construction material locally available. • High effluent quality	• High land space required

Important Sources of Information –

Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan
Pickford, J., 1991. The Worth of Water. Southampton Row, London, UK.
Loetscher T., 1998. SANEX Sanitation Expert Systems

<table>
<tr><th>SECONDARY PROCESS</th><th>TREATMENT INFORMATION</th></tr>
<tr><td>Filters
Anaerobic Filters/Fixed Bed Reactor/Fixed Film reactor


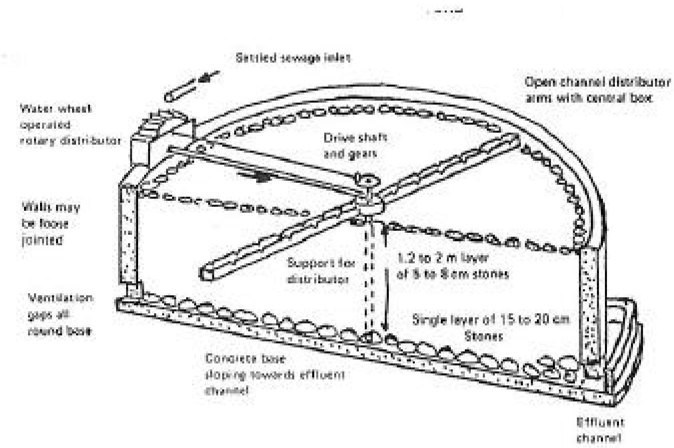
Source: Flow principle of anaerobic upflow filter after Ludwig, S. 1998</td><td>The anaerobic filter is suitable for domestic wastewater and all industrial wastewater that have a lower content of suspended solids. Anaerobic filters allow the treatment of non-settleable and dissolved solids by bringing 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.</td></tr>
<tr><td colspan="2">GENERAL INFORMATION
<u>Effluent quality:</u>
• 70-90% BOD removal in a well operated anaerobic filter.
• Moderate effluent quality
<u>Water Requirement</u>
• Since only receive liquid waste not suitable where water scarce or unreliable.
• Both greywater and blackwater can be flushed through the system
<u>O & M</u>
• High operation and maintenance
• Desludging required at regular intervals
• Cleaning of filter material required

Needs electrical power.
Low land requirement</td></tr>
<tr><th>ADVANTAGES</th><th>DISADVANTAGES</th></tr>
<tr><td>• Low land requirement</td><td>• High cost
• High operation and maintenance requirements
• Requires electricity</td></tr>
<tr><td colspan="2">Important Sources of Information –
Sasse, L. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries
Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan</td></tr>
</table>

<table>
<tr><th>SECONDARY PROCESS</th><th>TREATMENT INFORMATION</th></tr>
<tr><td>

Filters

Trickling Filters/Percolating Filters



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

</td><td>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 utilize the media in filter.</td></tr>
<tr><td colspan="2">

GENERAL INFORMATION

<u>Effluent quality:</u>

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

<u>Water Requirement</u>

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

<u>O & M</u>

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

Needs electrical power
Moderate land requirement

</td></tr>
<tr><th>ADVANTAGES</th><th>DISADVANTAGES</th></tr>
<tr><td>

- High effluent quality

</td><td>

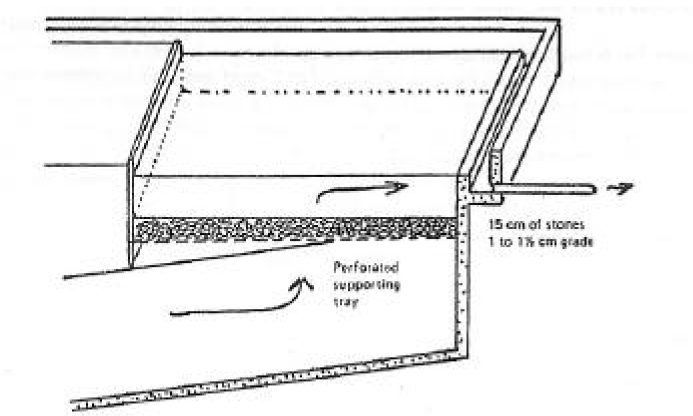
- High cost
- High operation and maintenance requirements
- Needs electrical power

</td></tr>
<tr><td colspan="2">Important Sources of Information –
Mann, H. T., Williamson, D., 1982. Water Treatment and Sanitation
Sasse, L. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries
Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan</td></tr>
</table>

7.2.3 Tertiary Processes

<table>
<tr><th>TERTIARY PROCESS</th><th>TREATMENT INFORMATION</th></tr>
<tr><td>Lagoons/Plots
Tertiary Lagoons
(No Diagram Available)</td><td>The treatment process of Tertiary Lagoons is similar to that of sedimentation tanks except on a much larger scale. The area of the lagoon at which the point of discharge is placed should be deeper than the rest of the pond to avoid algae being present in effluent, as algae flourish in depths of upto 1m. The effluent from the lagoons should be taken from the middle portion. Suspended matter may accumulate in lagoons, however if depths are adequate this does not prove offence.</td></tr>
<tr><td colspan="2">GENERAL INFORMATION
<u>Effluent quality:</u>
• Treatment quality performed on secondary treated effluent
• 40% BOD removed
• 40% Suspended solids removed
<u>Water Requirement</u>
• Since only receive liquid waste not suitable where water scarce or unreliable.
• High volume of water required
<u>O & M</u>
• Low operation and maintenance
• Requires maintenance of lagoon banks and control of mosquito breeding.

No electrical requirement.
High land requirement
Moderate Cost</td></tr>
<tr><td>ADVANTAGES</td><td>DISADVANTAGES</td></tr>
<tr><td>• Low operation and maintenance
• Construction material available locally
• No electrical requirement
• High Effluent Quality</td><td>• High land space required</td></tr>
<tr><td colspan="2">Important Sources of Information –
Mann, H. T., Williamson, D., 1982. Water Treatment and Sanitation</td></tr>
</table>

TERTIARY PROCESS	**TREATMENT INFORMATION**
Lagoons/Plots Banks' Clarifiers  ***Source: After*** *Mann, H. T., Williamson, D., 1982*	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.

GENERAL INFORMATION

Effluent quality:

- Treatment quality performed on secondary treated effluent
- 30% BOD removed
- 50% Suspended solids removed
- 25% E. Coli removed

Water Requirement

- Since only receive liquid waste not suitable where water scarce or unreliable.
- High volume of water required

O & M

- Low operation and maintenance
- Requires removal of solids, which accumulate on the upper surface of the gravel bed layer.

No electrical requirement.
High land requirement
Moderate Costs

ADVANTAGES	**DISADVANTAGES**
• Low operation and maintenance • Construction material available locally • No electrical requirement. • High Effluent Quality	• High land space required

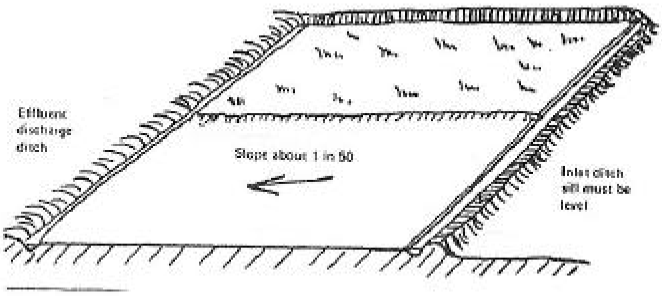
Important Sources of Information –

Mann, H. T., Williamson, D., 1982. Water Treatment and Sanitation

<table>
<tr><th>TERTIARY PROCESS</th><th>TREATMENT INFORMATION</th></tr>
<tr><td>

Lagoons/Plots

Grass Plots



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

</td><td>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.</td></tr>
<tr><td colspan="2">

GENERAL INFORMATION

Effluent quality:

- Treatment quality performed on secondary treated effluent
- 50% BOD removed
- 70% Suspended solids removed
- 90% E. Coli removed

Water Requirement

- Since only receive liquid waste not suitable where water scarce or unreliable.
- High volumes of water required

O & M

- Simple to construct.
- Low operation and maintenance
- Requires removal of solids but only when they are seen to physically prevent the flow
- Surplus grass needs to be removed

No electrical requirement.
High land requirement
Moderate Costs

</td></tr>
<tr><th>ADVANTAGES</th><th>DISADVANTAGES</th></tr>
<tr><td>

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

</td><td>

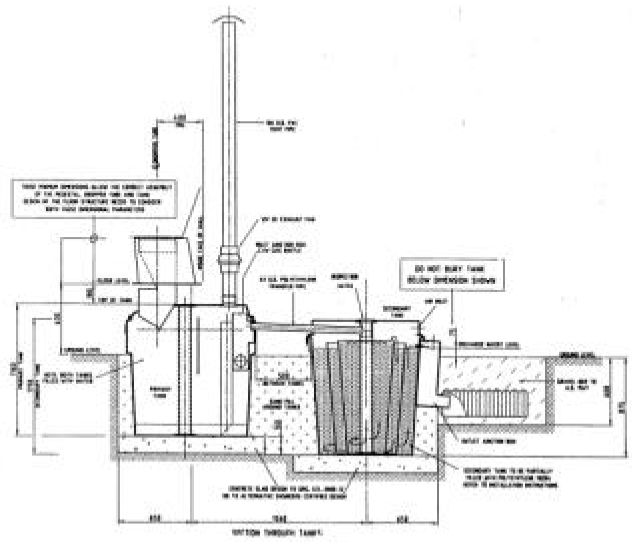
- High land space required

</td></tr>
<tr><td colspan="2">

Important Sources of Information –

Mann, H. T., Williamson, D., 1982. Water Treatment and Sanitation

</td></tr>
</table>

Tertiary Process	**Treatment Information**
Hybrid Toilet Systems (HTS)  *Source: Hybrid Toilet Systems, Gough Plastics Brochure*	The Hybrid Toilet System consists of a non-flushing, drop toilet which feeds directly into a septic tank filled with water (primary tank), which then delivers via displacement, clarified effluent to the secondary treatment unit. On completion of treatment the effluent is then dispersed to the ground via a gravel bed. Due to the small volumes entering the primary tank there is a long detention period which allows for effective breakdown of solids and efficient settling and clarification to occur with the remaining of the undigested solids settling to the bottom of the unit forming a sludge layer. In the secondary tank the effluent entering from the primary tank is directed along very specific ascending and descending flow paths. The majority of the secondary tank and its in built baffling system are filled with a polyethylene media. As the effluent flows up and down through these zones it is subjected to aerobic, facultative, and anaerobic treatment on four separate occasions which continues to kill pathogens. The treated effluent then exits the system and is sent to ground via a gravel bed.

GENERAL INFORMATION

Effluent quality:

- BOD_5 1mg/m^2, Non-Filtrable Residue (NFR) ,<1mg/l,
- Total N 1.2mg/l, Total P 0.89 mg/l. (Depending on primary loads)
- Faecal Colifrom <2 organisms/100ml.
- The holding time in the system was increased to include the life period of most pathogens, and decrease water borne diseases by using the Hybrid as a sanitation barrier in more remote communities.

Water Information

- The system is a wet system, whereby upon installation the tanks are filled with water. The system works through displacement where if 10L went into the system, approximately 10L would be displaced through the unit.
- The system is designed to operate around volumes generated by the population using the system as a toilet only. Waste from hand washing facilities may be introduced at the at the effluent exit point of the system.

O & M

- Construction of septic tank and upflow filter requires skilled labor
- Requires sludge removal on a regular basis, and disposal at a proper disposal site.

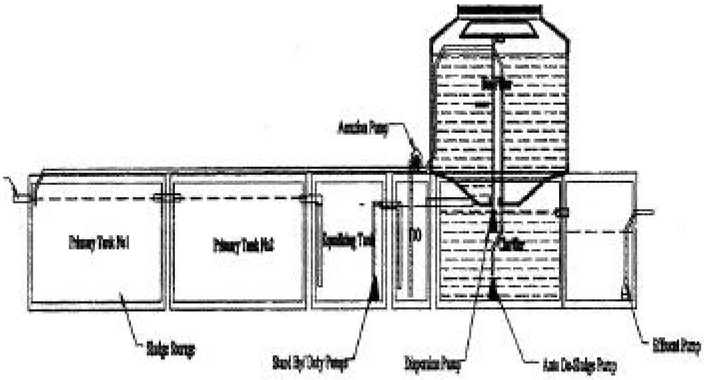
Requires electricity
Low land requirement

ADVANTAGES	**DISADVANTAGES**
• Low cost and low land space requirement. • Low operational and maintenance requirements • High Effluent Quality	• Accommodates blackwater only • Electricity required

Important Sources of Information –

Gough Plastics, The Hybrid Toilet System Brochure
Gough I., Langford M., Gough A., The Hybrid Toilet System: General Principles And System Design Drivers

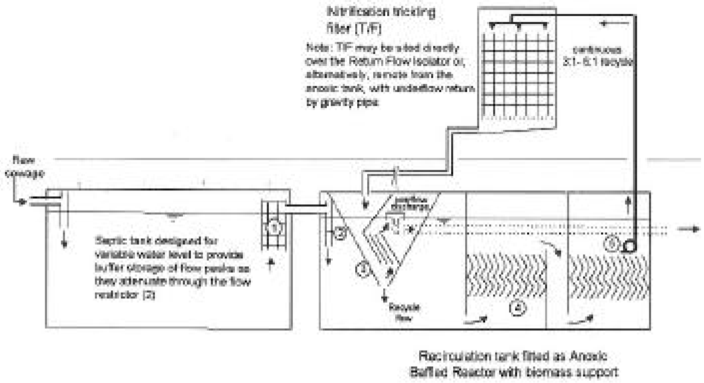
7.2.4 Package Plant Types

<table>
<tr><th>PACKAGE PLANT TYPES</th><th>TREATMENT INFORMATION</th></tr>
<tr><td>Plant Type
Enviroflow Biofilter Treatment Plant System


Source: After Enviroflow Wastewater Treatment Brochure</td><td>Enviroflow Plants treat both black and greywater through a two-stage bacterial digestion process followed by clarification and disinfection. Essentially wastewater is run from kitchens, toilets etc. through two treatment stages before clarification and disinfection. The first stage is carried out using anaerobic and aerobic bacteria inside a primary tank. Solids undergo digestion by bacteria and liquids containing soluble organic matter then passes to the second stage. The second stage has a biological trickling filter in which selected bacteria grow on a medium where wastes flow in contact with the air. Any bacterial cell matter that is separated in this step is kept in the effluent stream and allowed to settle out in the clarifying chamber. Following this the then clear effluent is passed to a disinfecting step where Chlorine is used to disinfect the effluent. The plants are capable of servicing from just 10 people to communities of 20,000 people as plants can be modified to suit such varying populations.</td></tr>
<tr><td colspan="2">GENERAL INFORMATION
<u>Effluent quality:</u>
• Effluent quality contains BOD_5 <20mg/l
• Suspended Solids <30mg/l
<u>Water Requirement</u>
• Since only receive liquid waste not suitable where water scarce or unreliable.
• High volumes of water requirement
<u>O & M</u>
• High operation and maintenance
• Manual provided for operation and maintenance
• Small pill kit tester for effluent monitoring

Needs electrical power.
Low land requirement.</td></tr>
<tr><th>ADVANTAGES</th><th>DISADVANTAGES</th></tr>
<tr><td>• Low land space required
• High effluent quality</td><td>• High operation and maintenance required.
• Requires electricity
• High cost</td></tr>
<tr><td colspan="2">Important Sources of Information –
Enviroflow Wastewater Treatment Brochure</td></tr>
</table>

PACKAGE PLANT TYPES	TREATMENT INFORMATION
Plant Type N-DN Biofilter Treatment Plant	The N-DN Biofilter treatment plant is a Reticulating Trickling Filter type. The concept of its operation and performance is similar to a reticulating sand or gravel filter. N-DN plants are designed for biological removal of nitrogen using the Nitrification-Denitrification (N-DN) process. Soluble BOD is removed by denitrification in the Anoxic chamber before the effluent is applied to the trickling filter. The BOD load to the trickling filter is reduced allowing the filter to be smaller in plants. This wastewater unit currently known as the NPL-6000 and is suitable for upto 6 people.



Source: After N-DN Biofilter Treatment Plant Brochure

GENERAL INFORMATION

Effluent quality:

- Effluent contains BOD_5 5-15 g/m^3
- Suspended Solids 10-20 g/m^3
- Ammonia Nitrogen 0.5-5 g/m3
- Total Nitrogen 15-25 g/m3
- Total Phosphorus Standard Plant – 4-10g/m^3 , Enhanced P removal 1-2g/m^3

Water Requirement

- Since only receive liquid waste not suitable where water scarce or unreliable.
- High volumes of water required.

Land Requirement

- The unit is 3.8m long, 1.3m wide and 2.1m deep with a total area of 5.07m^2.
- The disposal field requires an area of 200m^2

Doesn't require skill for operation
Needs electrical power.

ADVANTAGES	DISADVANTAGES
• High effluent quality • Low land requirements	• High maintenance. • Requires electricity • High cost

Important Sources of Information –

Neptune Pacific Ltd., On-site and Small Community Sewage Management with the N-DN Biofilter Treatment Plant

PACKAGE PLANT TYPES	TREATMENT INFORMATION
Plant Type Intermittent Decanted Extended Aeration System. (IDEA) (No Diagram Available)	The IDEA plant consists of two reaction tanks and is operated with sewage being continuously introduced into the first reaction tank. Aerators are provided in the process for mixing as well as to allow air into the biochemical reactions. Sewage then overflows into the second tank that operates on a fill and draw basis that is then intermittently decanted. Contents of the tank are left to settle for 30mins or so leaving the treated effluent on the surface. A special decanting device is used where effluent is drawn through. Flow is temp orarily placed in a flow balance tank. Effluent is then disinfected in a UV unit after which it is drained into a wet well for pumping to irrigation. Sludge removal is done daily and placed into a sludge storage tank.

GENERAL INFORMATION

Effluent quality:

- Expected effluent quality Total Nitrogen less than 10mg/l and often as low as 5mg/l.
- Normal sewage has 8-10mg/l of phosphorus. Effluent Contains 6-8mg/l.

Water Requirement

- Since only receive liquid waste not suitable where water scarce or unreliable.
- High volumes of water required because the IDEA plant operates with wastewater being continually being introduced into first reaction tank.

O & M

- High maintenance and Operation
- High technology requiring Skilled operation and Maintenance.
- Daily removal of sludge.

Needs electrical power.
No land requirements information available

ADVANTAGES	DISADVANTAGES
• High effluent quality	• High operation and maintenance. • Requires electricity • High cost

Important Sources of Information –

Sinclair, Knight, Merz, 1997 Review of Effluent Management Systems Castaway Resort

PACKAGE PLANT TYPES	TREATMENT INFORMATION
Plant Type Sequential Batch Reactors Cromaglass Unit  *Source: After Cromaglass Wastewater Treatment System*	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) in which fill and aeration occurs is the Solids Retention Section. 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 submersible aeration pump Section (B) is the continuing Aeration section where air and mixing are provided by pumps. Denitrification which is optional and is performed by creating anoxic conditions by closing off air to air intake pumps 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.

GENERAL INFORMATION

Effluent quality:

- Over 90-95% reduction of BOD and Suspended Solids.
- BOD_5 – 30mg/L, Total Suspendable Solids 30mg/L

Water Requirement

- Since only receive liquid waste not suitable where water scarce or unreliable.
- High volumes of water required because it is a continuously fed activated sludge process.

O & M

- High maintenance and Operation
- High technology requiring Skilled operation and Maintenance.

Needs electrical power.
Low land requirement

ADVANTAGES	DISADVANTAGES
• Low land space required • High effluent quality	• High operation and maintenance. • Requires electricity • High cost

Important Sources of Information –

Enviro-Technology Inc., 1998. Cromaglass Wastewater Treatment Systems

8: REFERENCES

1. Aqua Milieu Pty Ltd. Trading as Enviroflow, Enviroflow Biofilter Wastewater Treatment Plant Brochure.

2. Del Porto D., SPC Workshop on The Soltran II Non Polluting Biological Toilet and Wastewater garden, Suva, Fiji, 25 November 1996.

3. Enviro-Technology Inc., 1998. Cromaglass Wastewater Treatment Systems

4. Environment Equipment Pty Ltd. Rota-Loo Composting Toilet Brochure.

5. Environment Equipment Pty Ltd. Biolet Composting Toilet Brochure.

6. Gough I., Langford M., and Gough A. 1999. The Hybrid Toilet System: General Principles and System Design Drivers. Published by Lanfax Laboratories, Armidale NSW.

7. Gough Plastics Australia, The Hybrid Toilet System Brochure.

8. Khan, A.R. 1995. Appropriate Wastewater Treatment Processes for N-WFP, Pakistan, Master of Science Research of Loughborough University of Technology.

9. Loetscher T., 1998. SANEX Sanitation Expert Systems

10. Ludwig, S. 1998. DEWATS Decentralised Wastewater Treatment in Developing Countries, Bremen Overseas Research and development Association, Bremen.

11. Mann, H.T., Williamson, D., 1982. Water Treatment and Sanitation, Intermediate Technology Publications 1973, 1979, 1982., Printed in England by The Russell Press Ltd., Nottingham.

12. Mara, D. Sewage Treatment in Hot Climates, A Wiley Interscience Publication, John Wiley and Sons.

13. Neptune Pacific Ltd., On-site and Small Community Sewage Management with the N-DN Biofilter Treatment Plant

14. Pickford, J., 1991. The Worth of Water. Technical Briefs on health, water and sanitation. Intermediate Technology Publications 1991.103-105 Southampton Row, London, Printed by Russell Press Ltd., Nottingham.

15. Sinclair, Knight, Merz, 1997 Review of Effluent Management Systems Castaway Resort