Executive Summary

Waste or Wastewater Stabilization Ponds (WSPs) are large, man-made water bodies in which blackwater, greywater or faecal sludge are treated by natural occurring processes and the influence of solar light, wind, microorganisms and algae. The ponds can be used individually, or linked in a series for improved treatment. There are three types of ponds, (1) anaerobic, (2) facultative and (3) aerobic (maturation), each with different treatment and design characteristics. WSPs are low-cost for O&M and BOD and pathogen removal is high. However, large surface areas and expert design are required. The effluent still contains nutrients (e.g. N and P) and is therefore appropriate for the reuse in agriculture, but not for direct recharge in surface waters.

Advantages
Resistant to organic and hydraulic shock loads
High reduction of solids, BOD and pathogens
High nutrient removal if combined with aquaculture
Low operating cost
No electrical energy required
No real problems with flies or odours if designed and maintained correctly
Can be built and repaired with locally available materials
Effluent can be reused in aquaculture or for irrigation in agriculture
Disadvantages
Requires large land area
High capital cost depending on the price of land
Requires expert design and construction
Sludge requires proper removal and treatment
De-sludging (normally every few years)
Mosquito control required
If the effluent is reused, salinity needs to be monitored
Not always appropriate for colder climates

In  
Out

Blackwater, Faecal Sludge, Greywater, Brownwater, Faeces, Excreta

Factsheet Block Title
Introduction
Factsheet Block Body

Waste stabilization ponds are large man-made basins in which greywater, blackwater or faecal sludge can be treated to an effluent of relatively high quality and apt for the reuse in agriculture (e.g. irrigation) or aquaculture (e.g. macrophyte or fish ponds). They are semi-centralised treatment systems combined after wastewater has been collected from toilets (see also wastewater collection and user interface). For the most effective treatment, WSPs should be linked in a series of three or more with effluent being transferred from the anaerobic pond to the facultative pond and, finally, to the aerobic pond. The anaerobic pond is the primary treatment stage and reduces the organic load in the wastewater. The entire depth of this fairly deep man-made lake is anaerobic. Solids and BOD removal occurs by sedimentation and through subsequent anaerobic digestion inside the accumulated sludge (see also anaerobic digestion general). Anaerobic bacteria convert organic carbon into methane and through this process, remove up to 60% of the BOD.

In a series of WSPs, the effluent from the anaerobic pond is transferred to the
facultative pond, where further BOD is removed. The top layer of the pond receives oxygen from natural diffusion, wind mixing and algae-driven photosynthesis. The lower layer is deprived of oxygen and becomes anoxic or anaerobic. Settleable solids accumulate and are digested on the bottom of the pond. The aerobic and anaerobic organisms work together to achieve BOD reductions of up to 75%.

**Anaerobic** and facultative ponds are designed for BOD removal, while aerobic ponds are designed for pathogen removal (see also pathogens and contaminants). An aerobic pond is commonly referred to as a maturation, polishing, or finishing pond because it is usually the last step in a series of ponds and provides the final level of treatment. It is the shallowest of the ponds, ensuring that sunlight penetrates the full depth for photosynthesis to occur. Photosynthetic algae release oxygen into the water and at the same time consume carbon dioxide produced by the respiration of bacteria. Because photosynthesis is driven by sunlight, the dissolved oxygen levels are highest during the day and drop off at night. Dissolved oxygen is also provided by natural wind mixing.

The major disadvantages of WSPs are a rather long process of days to week (MARA & PEARSON 1998; ROSE 1999) and requirement of large areas of land far away from homes and public spaces for the construction (DEPARTMENT FOR INTERNATIONAL DEVELOPMENT 1998). However, because of the low capital and particularly low O&M costs it is a good option for decentralised treatments in developing countries. In addition, it is one of the few low-cost natural processes, which provides good treatment of pathogens.
Typical scheme of a waste stabilisation system: An anaerobic, facultative and maturation pond in series. Source: TILLEY et al. (2014)

Factsheet Block Title
Design Considerations
Factsheet Block Body

Anaerobic ponds are built to a depth of 2 to 5 m and have a relatively short detention time of 1 to 7 days. Facultative ponds should be constructed to a depth of 1 to 2.5 m and have a detention time between 5 to 30 days. Aerobic ponds are usually between 0.5 to 1.5 m deep with a detention time of 15 to 20 days. If used in combination with algae and/or fish harvesting (see Fish Pond), this type of pond is effective at removing the majority of nitrogen and phosphorus from the effluent. Ideally, several aerobic ponds can be built in series to provide a high level of pathogen removal.

Pre-treatment (see Pre Treatment Technologies) is essential to prevent scum formation and to hinder excess solids and garbage from entering the ponds. To prevent leaching into the groundwater, the ponds should have a liner. The liner can be made from clay, asphalt, compacted earth, or any other impervious material. To protect the pond from runoff and erosion, a protective berm should be constructed around the pond using the excavated material. A fence should be installed to ensure that people and animals stay out of the area and that garbage does not enter the ponds.

Only slightly polluted wastewater may be discharged directly into primary facultative ponds. Depending on the requirement for the final effluent in terms of pathogen reduction, only anaerobic and facultative ponds are necessary in some instances.

<table>
<thead>
<tr>
<th>Pond</th>
<th>BOD Removal</th>
<th>Pathogen Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerobic Pond</td>
<td>50 to 85%</td>
<td></td>
</tr>
<tr>
<td>Facultative Pond</td>
<td>80 to 95%</td>
<td></td>
</tr>
</tbody>
</table>
Maturation Pond | 60 to 80% | 90%


**Anaerobic Treatment Ponds (APs)**

Mini waste stabilisation ponds consisting of an anaerobic (right), facultative (middle) and aerobic pond (left) at the CREPA headquarter, in Ouagadougou, Burkina Faso and a large-scale waste stabilisation pond system in Maine (USA). Source: SPUHLER, D. (2006) (left) and EMERY, R. (2003) (right)

The main function of anaerobic ponds is BOD removal, which can be reduced 40 to 85% (WSP 2007). As a complete process, the anaerobic pond serves to:

- Settle undigested material and non-degradable solids as bottom sludge
- Dissolve organic material
- Break down biodegradable organic material

BOD removal in anaerobic ponds is governed by the same mechanisms that occur in all other anaerobic reactors (MARA et al. 1992) and anaerobic ponds do not or only rarely contain algae. The process (as in septic tanks) relies on the sedimentation of settable solids and subsequent anaerobic digestion in the resulting sludge layer. During anaerobic digestion, biogas is produced which could be collected by covering the anaerobic pond with a floating plastic membrane (PENA VARON 2004; WAFLER 2008). The recovered biogas can be used for heating, cooking or, if sufficient amounts can be collected for energy production (biogas combustion and biogas electricity small-scale).
Facultative Treatment Ponds (FPs)

Facultative Treatment Ponds are the simplest of all WSPs and consist of an aerobic zone close to the surface and a deeper, anaerobic zone. They are designed for BOD removal and can treat water in the BOD range of 100 to 400 kg/ha/day corresponding to 10 to 40 g/m2/day at temperatures above 20°C (MARA and PEARSON, 1998).

The algal production of oxygen occurs near the surface of aerobic ponds to the depth to which light can penetrate (i.e. typically up to 500 mm). Additional oxygen can be introduced by wind due to vertical mixing of the water. Oxygen is unable to be maintained at the lower layers if the pond is too deep, and the colour too dark to allow light to penetrate fully or if the BOD and COD in the lower layer is higher than the supply. As a result of the photosynthetic activities of the pond algae, there is a diurnal variation in the concentration of dissolved oxygen. At peak sun radiation, the pond will be mostly aerobic due to algal activity, while at sunrise the pond will be predominantly anaerobic (ERTAS et al. 2005).

The facultative pond serves to:

- Further treat wastewater through sedimentation and aerobic oxidation of organic material
- Reduce odour
- Reduce some disease-causing microorganisms if pH raises
- Store residues as bottom sludge

FPs loose ammonia into the air at high pH; and settle some nitrogen and phosphorus in the sludge. FPs can result in the removal of 80 to 95% of the BOD5 (SPERLING 2007), which means an overall removal of 95% over the two ponds (AP and FP). Total nitrogen removal in WSP systems can reach 80% or more, and ammonia removal can be as high as 95%. To remove the algae from aerobic pond, effluents’ rock filtration, grass plots, floating macrophytes and herbivorous fish can be used, but most commonly, the effluent flows directly in a final maturation pond.

Aerobic / Maturation Ponds (MPs)
Pathways of **BOD** removal in facultative waste stabilisation ponds. Source: WATER AND WASTEWATER ENGINEERING (2014) (right)

Whereas anaerobic and facultative ponds are designed for **BOD** removal, maturation or polishing ponds are essentially designed for pathogen removal and retaining suspended stabilised solids (MARA et al. 1992; SASSE, 1998; TILLEY et al. 2008). The size and number of maturation ponds depends on the required bacteriological quality of the final effluent. The principal mechanisms for faecal bacterial removal in facultative and maturation ponds are **HRT**, temperature, high **pH** (> 9), and high light intensity. **Virus** and microorganisms get also removed. If used in combination with algae and/or fish harvesting, this type of pond is also effective at removing the majority of nitrogen and phosphorus from the effluent (TILLEY et al. 2008). Some further information on the physical design is given in ARTHUR (1983) and the international Water and **Sanitation** Centre (2004).

**Factsheet Block Title**
**Health Aspects/Acceptance**
**Factsheet Block Body**

To prevent leaching, the ponds should have a liner. The liner can be clay, asphalt, compacted earth, or another impervious material. Although effluent from aerobic ponds is generally low in pathogens, the ponds should in no way be used for recreation or as a direct source of water for consumption or domestic use. A berm can protect from erosion or the invasion by vegetation and a fence can protect the lagoons from people and animals and prevent that garbage is thrown in. For the restricted and unrestricted reuse of the effluent in agri- and aquaculture, please refer to the **WHO** (2006) guidelines.

**Factsheet Block Title**
Cost Consideration
Factsheet Block Body

According to the International Water and Sanitation Centre (IRC), stabilisation ponds are the most cost-effective (semi-)centralised wastewater treatment technology for the removal of pathogenic microorganisms. However, this depends on the availability of land and its price. Stabilisation ponds also have the advantage of very low operating costs since they use no energy compared to other wastewater treatment technologies and only low-tech infrastructure (see also operation and maintenance and ensuring sustainability). This makes them particularly suitable for developing countries where many conventional wastewater treatment plants have failed because water and sewer utilities did not generate sufficient revenue to pay the electricity bill for the plant (IRC 2004) (see also financing projects). However, expert design is still required (see also developing human resources). Further, the ponds can be combined with aquaculture to locally produce animal feed (e.g. duckweed) or fish (e.g. fish ponds). Biogas may also be recovered for use when anaerobic ponds are covered with a floating plastic membrane (PENA VARON 2004) (see also reuse of biogas).

Factsheet Block Title
Operation and Maintenance
Factsheet Block Body


Scum that builds up on the pond surface should be regularly removed. Aquatic
plants that are present in the pond should also be removed as they may provide a breeding habitat for mosquitoes and prevent light from penetrating the water column. The WHO (WHO 2005 in MOREL & DINER 2006) does not promote pond systems if appropriate mosquito control measures are not guaranteed.

The anaerobic pond must be de-sludged approximately once every 2 to 5 years, when the accumulated solids reach one third of the pond volume. For facultative ponds sludge removal is even rarer and maturation ponds hardly ever need desludging. Sludge can be removed by using a raft-mounted sludge pump, a mechanical scraper at the bottom of the pond or by draining and dewatering the pond and removing the sludge with a front-end loader.

If the water is reused for irrigation, the salinity of the effluent should be controlled regularly in order to prevent negative impact on the soil structure.

Factsheet Block Title
At a Glance
Factsheet Block Body

Working Principle
In a first pond (anaerobic pond), solids and settleable organics settles to the bottom forming a sludge, which is, digested anaerobic by microorganism. In a second pond (facultative pond), algae growing on the surface provide the water with oxygen leading to both anaerobic digestion and aerobic oxidation of the organic pollutants. Due to the algal activity, pH rises leading to inactivation of some pathogens and volatilisation of ammonia. The last ponds serves for the retention of stabilised solids and the inactivation of pathogenic microorganisms via heating rise of pH and solar disinfection.
Almost all wastewaters (including heavily loaded industrial wastewater) can be treated, but as higher the organic load, as higher the required surface. In the case of high salt content, the use of the water for irrigation is not recommended.

90% BOD and TSS; high pathogen reduction and relatively high removal of ammonia and phosphorus; Total HRT: 20 to 60 days

Low capital costs where land prices are low; very low operation costs

Design must be carried out by expert. Construction can take place by semi- or unskilled labourers. High self-help compatibility concerning maintenance.

Very simple. Removing vegetation (to prevent BOD increase and mosquito breath) scum and floating vegetation from pond surfaces, keeping inlets and outlets clear, and repairing any embankment damage.
Reliability

Reliable if ponds are maintained well, and if temperatures are not too low.

Main strength

High efficiency while very simple operation and maintenance.

Main weakness

Large surface areas required and needs to be protected to prevent contact with human or animals.

Applicability

Wastewater for treatment in aerobic ponds should have a BOD$_5$ content below 300 mg/l (SASSE 1998). Facultative and anaerobic ponds may be charged with high-strength wastewater. However, bad odour cannot be avoided reliably with high loading rates. WSPs are among the most common and efficient methods of wastewater treatment around the world. They are especially appropriate for rural communities that have large, open and unused lands, away from homes and public spaces and where it is feasible to develop a local collection system. They are not appropriate for very dense or urban areas. WSPs are particularly well suited for tropical and subtropical countries because the intensity of the sunlight and temperature are key factors for their efficiency (IRC 2004). In cold climates, the HRT and loading may be adjusted. However, when mean temperatures fall below 12 °C during several month of the years, WSPs seem not to be appropriate (ARTUHR 1983).

WSP are also recommended for the treatment in order to reuse the effluent in agriculture and aquaculture, because of its effectiveness in removing nematodes (worms) and helminth eggs (WHO 2006, Volume II), while preserving some nutrients. If reuse is not possible, WSPs may not be adequate for areas sensitive to eutrophication (UNEP 2004).

Library References
Notes in the Design and Operation of Waste Stabilization Ponds in Warm Climates of Developing Countries

Anaerobic, facultative and maturation ponds as well as aerated lagoon systems are presented as an appropriate solution in developing countries where sewerage systems are present. The technical content was reviewed by Prof. Duncan Mara (University of Leeds, England). Detailed design, operation and maintenance guidance is given. Hence, this paper can be useful as a technical manual.


Compendium of Sanitation Systems and Technologies. 2nd Revised Edition

This compendium gives a systematic overview on different sanitation systems and technologies and describes a wide range of available low-cost sanitation
technologies.


**Biological Wastewater Treatment in Warm Climate Regions Volume 1**

Biological Wastewater Treatment in Warm Climate Regions Volume 1 gives a state-of-the-art presentation of the science and technology of biological wastewater treatment, particularly domestic sewage. The book covers the main treatment processes used worldwide with wastewater treatment in warm climate regions given a particular emphasis where simple, affordable and sustainable solutions are required. The 55 chapters are divided into 7 parts over two volumes: Volume One: (1) Introduction to wastewater characteristics, treatment and disposal; (2) Basic principles of wastewater treatment; (3) Stabilisation ponds; (4) Anaerobic reactors; Volume Two (also available in the SSWM library): (5) Activated sludge; (6) Aerobic biofilm reactors; (7) Sludge treatment and disposal.


**Waste Stabilisation Ponds**

Waste Stabilisation Ponds
Waste Stabilisation Ponds is the third volume in the series Biological Wastewater Treatment. The major variants of pond systems are fully covered, namely: facultative ponds, anaerobic ponds, aerated lagoons, maturation ponds. The book presents in a clear and informative way the main concepts, working principles, expected removal efficiencies, design criteria, design examples, construction aspects, operational guidelines and sludge management for pond systems.


**Training Material on Anaerobic Wastewater Treatment**

This training manual emphasizes basics of biogas technology as well as design principles and technical considerations. A sample design exercise and some technical drawings and sketches are also given.

Greywater Management in Low and Middle-Income Countries, Review of Different Treatment Systems for Households or Neighbourhoods

This report compiles international experience in greywater management on household and neighbourhood level in low and middle-income countries. The documented systems, which vary significantly in terms of complexity, performance and costs, range from simple systems for single-house applications (e.g. local infiltration or garden irrigation) to rather complex treatment trains for neighbourhoods (e.g. series of vertical and horizontal-flow planted soil filters).


Guidance Manual on Water Supply and Sanitation Programmes

Guidance Manual on Water Supply and Sanitation Programmes
This manual has been prepared as a tool to help improve DFID's (Department for International Development, United Kingdom) support for water supply and sanitation projects and programmes in developing countries. Its particular focus is on how DFID assistance can best meet the needs of the urban and rural poor for water supply and sanitation services.


**Corinna, Main - Corinna Sewer District**

Corinna, Main - Corinna Sewer District

**Advanced Integrated Wastewater Pond Systems**

Advanced Integrated Wastewater Pond Systems

Waste Stabilization Pond Systems are summarized and Advanced Integrated Wastewater Pond Systems (AIWPS) are investigated. Detailed study about each treatment units and reaction mechanisms are studied. Fecal coliform bacteria removal mechanisms, the effect of parameters such as temperature, pH, dissolved oxygen, organic loading, solar radiation on removal efficiency is investigated. Some of AIWPS applications are given, emphasizing removal efficiencies in every unit. Based on operational simplicity, low cost and high removal efficiencies (99% BOD5, suspended solids and coliform bacteria removal), AIWPS is highly recommended for up to 1000 mg/L BOD5 concentration. Because of its high coliform bacteria removal efficiency, the effluent of AIWPS may be used for irrigation purposes.

**Waste Stabilization Ponds and Constructed Wetlands Design Manual**


**Design Manual for Waste Stabilization Ponds in Mediterranean Countries**


**Waste Stabilization Ponds: A Design Manual for Eastern Africa.**

Community-Based Technologies for Domestic Wastewater Treatment and Reuse- options for urban agriculture

The report suggests that emerging trends in low-cost, decentralised naturally-based infrastructure and urban wastewater management which promote the recovery and reuse of wastewater resources are increasingly relevant. Technologies for these sanitation options are presented. The concept of managing urban wastewater flows at a decentralised or "intermediate" level, based on micro watersheds, is explored. Effluent treatment standards that are currently accepted in order to protect public health and safety are reviewed.


Index of dept/chem-eng/Biotech-Environ/FUNDAMENT

Index of dept/chem-eng/Biotech-Environ/FUNDAMENT

Waste Stabilisation Ponds
This document provides information and instructions on waste stabilisation ponds. Various case studies are mentioned, e.g. the wastewater-fed fishponds in Calcutta in India.


**Wastewater stabilization ponds: Principles of planning and practice.**

The book has been divided in two parts. Part A provides a comprehensive summary concerning the various aspects of constructing, operating and maintaining pond systems. It also considers aspects such as management and safety. Part B is intended for persons making the preliminary designs on which cost estimates and, hence, choices can be made. In particular, the appendix and annex provide a working example and a simple methodology to help the designer in preparing adequately detailed designs.

**Pond Treatment Technology**


**Philippines Sanitation Source Book and Decision Aid**

This Sanitation Sourcebook distils some of the core concepts of sanitation in a user-friendly format so that the book can serve as a practical reference to sanitation professionals and investment decision-makers, particularly the local governments. The annexe contains a practical collection of factsheets on selected sanitation system options.


**Guidelines for the safe use of wastewater excreta and greywater. Volume II. Wastewater Use in Agriculture**
Volume II of the Guidelines for the safe use of wastewater, excreta and greywater provides information on the assessment and management of risks associated with microbial hazards and toxic chemicals. It explains requirements to promote the safe use of wastewater in agriculture, including minimum procedures and specific health-based targets, and how those requirements are intended to be used. It also describes the approaches used in deriving the guidelines, including health-based targets, and includes a substantive revision of approaches to ensuring microbial safety.


Further Readings

**Compendium of Sanitation Systems and Technologies (Arabic)**

This is the Arabic version of the Compendium of Sanitation Systems and Technologies. The Compendium gives a systematic overview on different sanitation systems and technologies and describes a wide range of available low-cost sanitation technologies.
Facultative Lagoons

Short factsheet on the design, operation, maintenance and costs of facultative ponds in the United States.


Epuration des eaux usées par Lagunage à Microphytes et à Macrophytes en Afrique de l'Ouest et du Centre- Etat des lieux, performances épuratoires et critères de dimensionnement

Epuration des eaux usées par Lagunage à Microphytes et à Macrophytes en Afrique de l'Ouest et du Centre- Etat des lieux, performances épuratoires et critères de dimensionnement
Stabilization ponds are a very promising sustainable centralized wastewater treatment option for West Africa due to the favourable climate. Pilot studies could demonstrate their performance in the local context; however none of the full-scale applications works. Besides the poor economic situation and little political support, it is also the lack of training and research that contributes to this situation. This work presents the establishment of an international research collaboration network and main technical recommendations based on an exhaustive assessment on the state-of-the-art of stabilization ponds in the West-African context.

Language: French

**Basic Principles of Wastewater Treatment**

Basic Principles of Wastewater Treatment

Basic Principles of Wastewater Treatment is the second volume in the series Biological Wastewater Treatment, and focusses on the unit operations and processes associated with biological wastewater treatment. The major topics covered are: microbiology and ecology of wastewater treatment, reaction kinetics and reactor hydraulics, conversion of organic and inorganic matter, sedimentation,
The purpose of this guide is to assist local contracting authorities and their partners in identifying those sanitation technologies best suited to the different contexts that exist within their town. The first part of the guide contains a planning process and a set of criteria to be completed; these assist you in characterizing each area of intervention so that you are then in a position to identify the most appropriate technical solutions. The second part of the guide consists of technical factsheets which give a practical overview of the technical and economic characteristics, the operating principle and the pros and cons of the 29 sanitation technology options most commonly used in sub-Saharan Africa.

Environmentally sound technologies in wastewater treatment for the implementation of the UNEP/GPA "Guidelines on Municipal Wastewater Management"

Environmentally sound technologies in wastewater treatment for the implementation of the UNEP/GPA "Guidelines on Municipal Wastewater Management"

Technical information on environmentally sound technologies in wastewater treatment.


Case Studies

Lagunas de Estabilizacion para Descarga de Liquidos de Camiones Atmosfericos

Lagunas de Estabilizacion para Descarga de Liquidos de Camiones Atmosfericos
This publication deals with the feasibility of waste stabilisation ponds for the simultaneous treatment of collected sludge (by vacuum trucks) and wastewater from the domestic sewer system. The principal objective of the study was to assess if existing treatment ponds could be used in the future as thickening ponds for the sludge.


Language: Spanish

**Ecological Sanitation and Reuse of Wastewater. Ecosan. A Thinkpiece on ecological sanitation**

Ecological Sanitation and Reuse of Wastewater. Ecosan. A Thinkpiece on ecological sanitation

![Image of Ecological Sanitation and Reuse of Wastewater. Ecosan. A Thinkpiece on ecological sanitation](image)

This paper shows that there are comprehensive experiences and available technologies that meet new and sustainable sanitation requirements. Ecological sanitation constitutes a diversity of options for both rich and poor countries, from household level up to wastewater systems for mega-cities and needs to become recognised by decision-makers at all levels.

**Sewage Fed Aquaculture Systems of Kolkata. A Century-old Innovation of Farmers**

Case Study on the fishponds in sewage-fed lagoons in Kolkata.


**Water for Urban Agriculture**

Various case studies on the reuse of pond and lagoon treated water in urban agriculture.


Training Material
Faecal Sludge Management. Lecture Notes

This module pays special attention to the haulage, treatment and reuse or disposal of faecal sludge. It covers both technical and non-technical (socio-cultural, economic, political etc.) aspects and provides practical information on design, financing and planning of faecal sludge treatment plants.


Design manual for designers, builders and operators on the design and operation of artificially constructed wetlands and waste stabilization ponds. The supporting information includes a standard systems approach which can be adopted universally; the theoretical background on the biological, chemical and physical processes of each method, the current state of the technology and technical
knowledge on how to design, operate and maintain them; and theoretical knowledge on how best the models may be used to describe the systems.


Awareness Raising Material

**FS Management - Review of Practices, Problems and Initiatives**

FS Management - Review of Practices, Problems and Initiatives

A study on management and institutional aspects regarding the challenges and possible improvements in managing faecal sludge.


Important Weblinks

**Clinton Water District. Case Study of the Facultative Lagoon System**


The Clinton Water District provides a secondary level of wastewater treatment by
using a facultative lagoon system. Clinton’s lagoon system was constructed in 1987. The two lagoons are operated in series and cover approximately 26 acres.