Executive Summary

Different types of constructed wetlands can be combined in order to achieve a higher treatment efficiency by using the advantages of individual systems. Most hybrid constructed wetlands combine vertical filter and horizontal filter stages. The vertical- horizontal filter system was originally designed in the late 1950s and the early 1960s but the use of hybrid systems was very limited. In the 1980s hybrid constructed wetlands were built in France and United Kingdom. At present, hybrid constructed wetlands are in operation in many countries around the world. They need expert design, but they can be built mostly with locally available material and the community can be trained for operation and maintenance. The effluent can be used for e.g. irrigation and aquaculture or safely be discharged to receiving water bodies.

Advantages
In general they have a higher treatment effect than single systems, especially for nitrogen, because the advantages of the different filters can be combined. As long as no free-surface filter is involved, they do not lead to increased mosquito breeding.
Construction can provide employment to local labourers
Utilisation of natural processes
Electricity generally only required for pumps
Process stability
Disadvantages
Very space consuming
Expert construction knowledge and experience needed
Requires expert design and supervision
Moderate capital cost depending on land, liner, fill, etc.; low operating costs
Pre-treatment is required to prevent clogging
Not very tolerant to cold climates

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Factsheet Block Title
Introduction
Factsheet Block Body

Constructed wetlands are secondary treatment facilities for household (blackwater or greywater, in some cases also brownwater) and/or biodegradable municipal or industrial wastewater. Constructed wetlands are a treatment step of DEWATS systems and they can even be used as a tertiary treatment system for polishing after [8209-activated sludge] or [8215-trickling filter] plants (HOFFMANN et al. 2010). The plants grown in the wetland may be the used for composting or biogas production (see also [7228-composting small scale], [8279-composting large scale] or [7034-anaerobic digestion]). Effluents, if they correspond to the WHO guidelines (see also WHO 2006): Guidelines for the safe use of wastewater excreta and greywater. Volume I, Volume II, Volume III and Volume IV) may be used for [8271-fertigation].

Basically, there are three different types of constructed wetlands (CWs). They are classified according to the water flow regime as:

- [8257-Free surface constructed wetlands]
- [8259-Horizontal flow constructed wetlands]
These three types of CWs may be combined with each other in hybrid constructed wetlands in order to exploit the specific advantages of the different systems.

One of the main advantages of CWs is that they are natural systems and thus not require chemicals, energy or high-tech infrastructure. Moreover, they are suited to be combined with aquaculture or sustainable agriculture ([7597-irrigation]).

Almost every type of constructed wetlands can be combined to fit different types of wastewater. However, hybrid systems are comprised most frequently of [8261-vertical flow] and [8259-horizontal flow] systems arranged in a staged manner. Horizontal flow systems cannot provide nitrification because of their limited oxygen transfer capacity. Vertical flow systems, on the other hand, do provide good conditions for nitrification but denitrification does not really occur in these systems. In hybrid systems (also sometimes called combined constructed wetland) the advantages of the horizontal and vertical flow systems can be combined to complement processes in each system to produce an effluent low in BOD, which is fully nitrified and partly denitrified and hence has much lower total-N outflow concentrations (VYMAZAL 2005). At present, hybrid constructed wetlands are in operation in many countries around the world and they are used especially when removal of ammonia-N and total-N is required (VYMAZAL 2010).

Many of these hybrid systems are based on the original hybrid systems developed by Seidel at the Max Planck Institute (Germany). The design consists of two stages of several parallel vertical flow beds (usually planted with Phragmites australis), followed by two or three horizontal beds (planted e.g. Typha or Carex). In these systems, the vertical flow beds are loaded with pre-treated wastewater for 1–2 days, and then allowed to dry out for 4–8 days. The thin crust of solids that forms on top of the vertical flow beds is mineralised during the rest period (VYMAZAL and KRÖPFELOVÁ 2011).

In the mid-1990s, Johansen and Brix introduced a horizontal-vertical flow hybrid system with a large horizontal flow bed placed first and a small vertical flow bed as the second stage. In this system nitrification takes place in the vertical flow stage at the end of the process sequence. If nitrate removal is needed, it is necessary to
pump the effluent back to the front end of the system where denitrification can take place in the less aerobic horizontal flow bed using the raw feed as a source of carbon needed for denitrification (VYMAZAL and KRÖPFEOVÁ 2011).

Two stage HF-VF hybrid constructed wetland based on Brix and Johansson. Source: VYMAZAL (2005)

The two-stage horizontal-vertical-flow constructed wetland system consist of three basic units (BRIX and JOHANSON 1999):
1. A mechanical pre-treatment step, usually a two or three-chamber settler, for removal of large particles and settleable materials.
2. A horizontal subsurface flow sand or gravel-based constructed reed bed for TSS and BOD removal (and denitrification if recirculation is applied).
3. An intermittently-loaded vertical flow constructed wetland for nitrification.

### Factsheet Block Title
### Costs Considerations
### Factsheet Block Body

Hybrid systems are more expensive than non-hybrid systems ([8257-free surface-flow constructed wetlands], [8259-horizontal] and [8261-vertical flow constructed wetlands]). A larger area is required and they are more complicated and complex to operate, especially for adjustment and monitoring of the loads (HOFFMANN et al. 2010). However, compared to other intensive high-rate aerobic treatment options (e.g. [8209-activated sludge]), constructed wetlands are natural systems, which work extensively. That means treatment may require more land and time, but you can save costs because there is no or just a low energy need. Furthermore, there is no need for sophisticated equipment, expensive spare parts or chemicals (GAUSS 2008).

### Factsheet Block Title
### Operation and Maintenance
### Factsheet Block Body

Basically, O&M is similar to [8259-horizontal flow constructed wetlands] or [8261-vertical flow constructed wetlands]. The difficulty is to ensure that the system is adjusted and the filters loaded correctly. That means it needs expert knowledge and skilled operators. It should be considered that a wetland system will require maintenance for the entire duration of its life.
The constructed wetland in the peri-urban area of Bayawan, Philippines, is designed for 700 people. Pre-treated wastewater is pumped into the header tanks; from there it flows by gravity to the vertical filer and later to the horizontal filter. Source: LIPKOW and MUENCH (2010)

Factsheet Block Title
Health Aspects
Factsheet Block Body

The risk of mosquito breeding in warm countries is low as long as there is no open water surface (e.g. [8257-free surface constructed wetlands]). It should be ensured that residents do not come in contact with the sludge/wastewater in the pre-treatment facility nor with the influent of the filter because of the risk if infection (TILLEY et al. 2008)

The effluents can generally meet the standards for pathogen levels for safe discharge to the environment without further treatment. In case of domestic wastewater, the situation could be different and for safety reasons disinfection (by tertiary treatment) might be necessary, depending on the intended reuse application (HOFFMANN et al. 2010).

The biggest health risk arises from settled wastewater in the pre-treatment facility; this should be considered during inspections and emptying. A proper emptying process (human powered or motorised) can decrease the health risks (TILLEY et al. 2008). After that, also sludge must be treated correctly, for example in [8223-drying
Any type of constructed wetlands may be combined with each other in order to exploit the specific advantages of the different systems. In general, horizontal and vertical flow filters are combined in series.

Hybrid constructed wetlands have a good performance and if land is available they are able to treat wastewater for bigger communities in peri-urban areas (see case study LIPKOW and MUENCH 2010).

If designed and operated correctly they have very high performance, because the advantages of horizontal and vertical flow filter beds are combined.

Capital costs are higher than for single constructed wetlands, because the system requires a lot of land. Furthermore, costs depend on the prices of the filter medium (sand or gravel).

O&M by trained labourers, most of construction material locally available, except filter substrate could be a problem. Construction needs expert design.

Emptying of pre-settled sludge, removal of unwanted vegetation, cleaning of inlet/outlet systems.

Treatment performance is satisfactory as long as the system is operated correctly. Clogging of the filter bed is a main risk of constructed wetlands.
Main strength

Hybrid constructed wetlands combine various types of constructed wetlands in order to achieve higher treatment effect especially for nitrogen removal.

Main weakness

Very large surface area required, as well as extensive construction knowledge and experience, risk of clogging if waste water is not well pre-treated, high quality filter material is not always available and expensive; expertise required for design, construction and monitoring (MOREL and DIENER 2006).

Applicability

Constructed wetlands are generally used as secondary treatment process, which means that the wastewater is treated in a primary treatment step to remove solids and prevent clogging. Primary treatments, such as [septic tanks], [anaerobic baffled reactors], [imhoff tanks], [biogas settlers], [UASB reactors], or [compost filter] are the most suited lower the BOD and prevent clogging of the constructed wetland.

Hybrid constructed wetlands, even though natural (extensive) treatments such as [free surface flow], [horizontal] and [vertical flow constructed wetland] require pumps and some skilled operation and maintenance to adjust the filter loads correctly. Therefore they are most suited so small communities organised enough to thoroughly plan and maintain the wetland for the duration of its life.

Constructed wetlands are best suited to warm climates but can be designed to tolerate some freezing and periods of low biological activity (TILLEY et al. 2008). Shade from plants and protection from wind mixing is limiting the dissolved oxygen in the water.

Constructed wetlands allow for the combination with aquaculture and agriculture ([irrigation]) what contributes to the optimisation of the local water and nutrient cycle.

Library References
This document contains the design principles of two-stage constructed wetlands and a basic system for many more hybrid constructed wetlands.


**Constructed Wetlands: A Promising Wastewater Treatment system for Small Localities. Experiences from Latin America**

This report provides an overview of how constructed wetlands serve as natural wastewater treatment systems. It focuses especially on the subsurface horizontal flow type—a technology that has high potential for small and medium-size communities because of its simplicity, performance reliability, and low operation
and maintenance requirements. The ability of this wetland to reduce pathogens renders the effluent suitable for irrigation of certain crop species if additional health and environmental protection measures are taken. This report describes several experiences with constructed wetland schemes in Central and South America: a full-scale pilot plant in Nicaragua, a community-managed constructed wetland scheme in El Salvador, and other systems in Colombia, Brazil, and Peru.


**Technology Review of Constructed Wetlands**

This publication intends to help spread awareness and knowledge about the technology of subsurface flow constructed wetlands in developing countries. Constructed wetlands (CWs) can be used as part of decentralised wastewater treatment systems, due to their “robust”, “low-tech” nature with none or few moving parts (pumps) and relatively low operational requirements. CWs can be used for the treatment of domestic and municipal wastewater or greywater, and play an important role in many ecological sanitation (ecosan) concepts.


**Constructed Wetland for a Peri-urban Housing Area Bayawan City, Philippines**
Case study on constructed wetlands for a peri-urban housing area. Septic tanks are used to pre-treat the sewage. The pre-treated wastewater is transported through a small-bore sewer system.


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

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).

Compendium of Sanitation Systems and Technologies

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


Horizontal Sub-Surface Flow and Hybrid Constructed Wetlands Systems for Wastewater Treatment

Horizontal Sub-Surface Flow and Hybrid Constructed Wetlands Systems for Wastewater Treatment
This essay describes the horizontal sub-surface flow and the two basic designs of hybrid constructed wetlands for wastewater treatment.


**Constructed Wetlands for Wastewater Treatment**

This document explains how constructed wetlands work and there is a collection of different wetlands all over the world.


**A three-stage experimental constructed wetland for treatment of domestic sewage: First 2 years of operation**

A three-stage experimental constructed wetland for treatment of domestic sewage: First 2 years of operation

Hybrid constructed wetland systems have recently been used to treat wastewaters
where high demand for removal of ammonia is required. However, these systems have not been used too often for small onsite treatment systems. This study describes an experimental system for mechanically pre-treated wastewater.


Further Readings

**Treatment of Domestic Sewage in a Two-Stage Constructed Wetland**

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**Constructed Wetlands - Treating Wastewater with Cenoses of Plants and Microorganisms**

Constructing Wetlands – Treating Wastewater with Cenoses of Plants and Microorganisms

The underlying philosophy of phytoremediation research at UFZ (Centre for Environmental Research) is to exploit and to optimise the processes in the rhizosphere. Low-cost, simple systems will be developed to control the environmental problems of different countries in several continents irrespective of their industrial capabilities and conditions – without losing sight of the key principle of cleaning up polluted environmental media in a natural, ecologically balanced way.

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

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DEWATS

DEWATS

Exhaustive report on technological, operational and economic aspects of
decentralised waste water treatment systems. Spreadsheet examples support the reader in designing and planning waste water treatment systems components. SASSE, L. BORDA (1998): DEWATS. Decentralised Wastewater Treatment in Developing Countries. Bremen: Bremen Overseas Research and Development Association (BORDA)

**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.


**Constructed Wetlands Manual**

This manual has been prepared as a general guide to the design, construction,
operation and maintenance of constructed wetlands for the treatment of domestic wastewater as well as introduction to the design of constructed wetland for sludge drying.


**Horizontal Sub-Surface Flow and Hybrid Constructed Wetlands Systems for Wastewater Treatment**

Horizontal Sub-Surface Flow and Hybrid Constructed Wetlands Systems for Wastewater Treatment

This essay describes the horizontal sub-surface flow and the two basic designs of hybrid constructed wetlands for wastewater treatment.


**Constructed Wetlands for Wastewater Treatment**

Constructed Wetlands for Wastewater Treatment
This document explains how constructed wetlands work and there is a collection of different wetlands all over the world.


These guidance notes are designed to provide state governments and urban local bodies with additional information on available technologies on sanitation. The notes also aid in making an informed choice and explain the suitability of approaches.


Decentralised Wastewater Management Using Constructed Wetlands

Decentralised Wastewater Management Using Constructed Wetlands
This paper describes the importance of small-scale decentralised wastewater treatment using reed bed treatment systems (constructed wetlands) in Nepal. It shows how public/community participation can support small-scale construction work while ensuring checks on quality and price of construction, including examples.


**Ecodesign: The Bottom Line**

There is no single design solution to sanitation. But there are universal principles for systematically and safely detoxifying human excreta, without contaminating, wasting or even using water. Ecological sanitation design — which is focused on sustainability through reuse and recycling — offers workable solutions that are gaining footholds around the world, as Nature explores on the following pages through the work of Peter Morgan in Zimbabwe, Ralf Otterpohl and his team in Germany, Shunmuga Paramasivan in India, and Ed Harrington and his colleagues in California.


**Case Studies**

**Constructed Wetland for a Peri-urban Housing Area Bayawan City, Philippines**

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in El Salvador, and other systems in Colombia, Brazil, and Peru.


**Wastewater treatment using constructed wetlands Tirana, Albania - draft**

Wastewater treatment using constructed wetlands Tirana, Albania - draft

Within the BMZ (German Federal Ministry for Economic Cooperation and Development) financed project on “Advice on the Decentralisation of the Water and Sewerage Sector in Albania” the GIZ and MPWT (Albanian Ministry of Public Works and Transport) initiated the pilot constructed wetland to raise awareness for low cost, appropriate and decentralised sanitation technologies in line with EU standards. It is aimed to be used as a model treatment plant by the main actors of the sector for training, demonstration, research and replication in peri-urban and rural areas of Albania.


**Constructed Wetlands for Wastewater Treatment and Wildlife Habitat**

Constructed Wetlands for Wastewater Treatment and Wildlife Habitat
This document provides brief descriptions of 17 wetland treatment systems from that are providing significant water quality benefits while demonstrating additional benefits such as wildlife habitat. The projects described include systems involving both constructed and natural wetlands, habitat creation and restoration, and the improvement of municipal effluent, urban stormwater and river water quality. Each project description was developed by individuals directly involved with or very familiar with the project in a format that could also be used as a stand-alone brochure or handout for project visitors.


**A three-stage experimental constructed wetland for treatment of domestic sewage: First 2 years of operation**

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Treatment Wetlands

Issue 12 of Sustainable Sanitation Practice (SSP) on „Treatment wetlands“ includes 6 contributions: (1.) the Austrian experience with single-stage sand and gravel based vertical flow systems with intermittent loading (the Austrian type is for treating mechanically pre-treated wastewater), (2.) the French experiences with two-stage vertical flow systems treating raw wastewater. (3.) EcoSan Club’s experiences with TWs in Uganda, (4.) results from multi-stage TW treating raw wastewater in Morocco. (5.) results from horizontal flow experimental systems from Egypt, and (6.) experiences from Denmark and UK on reed beds treating excess sludge from activated sludge plants.


Training Material

Small-scale Constructed Wetlands for Greywater and Total Domestic Wastewater Treatment

Small-scale Constructed Wetlands for Greywater and Total Domestic Wastewater Treatment
This training material quantifies and characterises grey- and total domestic wastewater production and exemplifies designing of small-scale horizontal and vertical flow constructed wetland system.


**Technical Lecture Greywater Management**

This PDFPresentation quantifies and characterises grey- and total domestic wastewater production and exemplifies designing of small-scale horizontal and vertical flow constructed wetland system.


Awareness Raising Material

**Healthy Wetlands, Healthy People: A Review of Wetlands and Human Health Interactions**

Healthy Wetlands, Healthy People: A Review of Wetlands and Human Health Interactions
Despite the production of more food and extraction of more water globally, wetlands continue to decline and public health and living standards for many do not improve. Why is this – and what needs to change to improve the situation? If we manage wetlands better, can we improve the health and well-being of people? Indeed, why is this important? This report seeks to address these questions.


Important Weblinks

http://www.youtube.com/

http://www.youtube.com/

A short movie about the constructed wetland treatment system in Bayawan-City, Philippines.