Report III

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Short Term Expert Report III:

Implementation of a soil filter treatment plant for water reuse in Bayawan, Oriental Negros

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0 Abbreviations used in the Report

BOD	Biological Oxygen Demand (corresponds to the concentration of soluble biodegradable organic substances)
CW	Constructed Wetland
LGU	Local Government Unit
O&M	Operation and Maintenance
PE	Polyethylene
P.E.	Population Equivalents
PHP	Philippine Peso
SF	Soil Filter
TOR	Terms of Reference
UfZ	Umweltforschungszentrum Halle-Leipzig GmbH (Environmental Research Centre)
UP	University of the Philippines, Manila
WHO	World Health Organisation
WWT	Waste Water Treatment
WWTP	Waste Water Treatment Plant

1 Executive Summary

In Bayawan, Oriental Negros, a Constructed Wetland (CW) for municipal application is being installed. The project was prepared during a first mission in February 2005. During a second mission in December 2005, major construction steps could be supervised and the decision process regarding maintenance & operation initiated.

The constructed wetlands fit well into the ecosan concept, initiated by the GTZ, at places of intensive agglomeration of people, because this technology has low operation costs, is easy to maintain and is reliable in large as well as in small sizes. This technology can be applied in small settlements, in parts of rural cities, isolated hotels, schools and industry. Two-stage soil filters (SFs), or CWs can achieve a high hygienic quality of the effluent. A comprehensive description of the major features is given in report I.

During the previous missions a close co-operation with a local partner was started, who performed the detail planning. During the third mission the treatment plant could be put into partial operation. The state of project development is the following:

The second batch of inhabitants moved into their houses in the second week of May, 2006. Now 150 houses are in use, which amounts to a population of about 700.

Since the second mission until the end of the third mission, the following progress has been achieved:

- Planting the reeds in cell 2
- Connection of the main sewer to the pump sump (prior to the mission, June, 2006)
- Water consumption data available
- Redesign: replacement of the main distribution pump by dividing the filter area of cell 1 into 4 identical fields, each with a separate mechanical distribution system, reducing costs and energy, (prior to the mission, June, 2006)
- Final filter media installation
- Installation and calibration of the first of the four distribution systems
- Interim waste water application to cell 2
- last draft of the O&M manual
- O&M teams and responsibilities practically set
- Monitoring scheme finalised
- Dissemination: Brochure for potential users is ready for layout; potential users and multipliers are already visiting the plant; internet presentation of the project (www.bayawancity.gov.ph)

Aerial view of the WWTP

The following minor technical works left to do, with realistic time frames, are:

- Installation of the distribution systems in the other three fields of cell 1 (July 2006)
- Installation of the small main feeder pump (July, 2006)
- Finishing the distribution system of cell 2 (July, 2006)
- Installation of an overflow from the outflow tank, connected to the sea

- Planting cell 1 (July 2006)
- Starting routine operation (August 2006).

The following points are well in the agenda, but cannot yet be scheduled:

- Final organisational setting
- Startup of routine monitoring
- Transfer of O&M tasks to a person out of the beneficiaries.

2 Introduction

The prevalence of waterborne diseases is mainly caused by the absence of treatment facilities for municipal sewage treatment all over the Philippines. Latest publications estimate that the Philippine economy loses more than 3 Billion Pesos annually through avoidable health costs due to losses in direct income and medical expenses for in-patients and outpatients that are treated for water borne diseases (“Environmental Monitor 2003”, DENR and Worldbank). The problem of sanitation is specifically significant for the poor and underprivileged sector. Within this sector, the children are most vulnerable. The untreated wastewater also threatens the environment by contaminating water bodies and coastal zones. Although much has been done in the water supply sector during the last decade, very little effort and progress can be seen in the sanitation and sewer sector.

The relation between the current sanitation situation and the occurrence of water born diseases is clearly demonstrated by the observation, that during rainy seasons diarrhoea cases increase together with dengue fever and typhoid.

Via the sandy soils, prevailing in the region, pathogens, viruses and nitrates can easily reach and contaminate the groundwater. Since in Bayawan City more than 30 % of the urban population are not served by a safe drinking water source (city water supply) but instead get their water mostly from shallow wells, there is a great risk for infections. This shows the importance of waste water disinfection measures, combined with the biological treatment.

In some situations, for example in Bohol, the underground is formed by calciferous rock, which is very porous. There deep hollows without natural outflow exist, where the waste water directly contaminates the groundwater resource.

But also the environmental aspect is of great concern. For example the waste water outfall into the valuable coral reefs leads to changes in the biodiversity and on the medium and long run will cause the development of the tourism as important income source to fail.

Thus, the construction of reliable WWTPs, which are affordable and easy to maintain and operate, is of great importance. In the previous report, the disadvantages of centralised systems with highly sophisticated technical treatment plants have been pointed out.

Technical treatment plants in small systems are usually not reliable, especially with fluctuating population, and they need much electricity. Instead, constructed wetlands are usually tolerant against load fluctuation and require a very low maintenance and energy input. For the different CW systems see report I. The special feature of CWs is the option to receive a water which meets the standards of the WHO for irrigation even of vegetables to be eaten raw. The design of a CW with special hygienic treatment performance could be worked out in a joint research project, which was co-ordinated by UfZ and financed by the German Federal Ministry of Education and Research.

Only in settlements with concentrated core zones, centralised systems make sense. To reduce the sewer costs, which in some cases amount to up to 80% of the total costs for the sewage system, there is an option, to do the mechanical pre-treatment onsite at the houses. Here the processing of the faecal sludge has to be addressed. Sand filter beds with vegetation can offer an interesting solution for the direct conversion of the sludge into compost.

Along with the installation of the treatment plants the organisation of maintenance and operation should be standardised. This could be done through regular workshops for the operation personnel and by the organisation of "WWTP-neighbourhoods". Operation also includes a regular system for monitoring the treatment performance. That leads to the question of installing lab capacity, especially under the aspect, that in the warm climate the water has to be analysed very soon after sampling.

3 Background and goals of the mission

In the Philippines about 25% of the population have no access to sanitation services. On-site sanitation is most common option in the Philippines, but due to poor operation and maintenance it is also the main source of groundwater pollution and water born diseases. In general more than 90% of the sewage is not treated and disposed in an environmental manner.

The German Technical Cooperation - GTZ, through its Water, Sanitation and Solid Waste Program promotes Integrated Water Resources Management with innovative ideas in rural water supply and sustainable sanitation on a participatory approach. The Program aims to demonstrate pilot solutions that shall address the problem of sustainability due to high capital and operation & maintenance cost of centralized sewer systems. One possible alternative for rural and peri-urban areas is the construction of decentralized sanitation facilities like a "wetland treatment system," with low construction and maintenance costs. Although this innovative technique is accepted worldwide and proven efficient, such a solution has not been applied to the treatment of domestic waste water in the Philippines until today.

GTZ and the City of Bayawan signed a Memorandum of Agreement for the mutual benefit of implementing a constructed wetland last April 2005. Within the framework of this agreement, the GTZ Water Program shall assist in piloting this low-cost technology for the treatment of domestic wastewater from a housing project area for fisherfolks. The potential of replicating this technology will also be of primary interest of the cooperation.

Project implementation is mainly coordinated by the GTZ Water, Sanitation and Solid Waste Program. A international and a local expert are responsible for the planning and design component of the wetland treatment plant. This team, in close coordination with the Bayawan City Engineering Office, has prepared all detailed engineering design plans, program of work, and corresponding bill of quantities for implementation.

GTZ in partnership with the project team contributes through supervision, assistance in social preparation and stakeholder participation. GTZ also supports the dissemination of lessons learned through their partner organisations, the GTZ network, and possibly with its partner countries overseas.

Relevant stakeholder and project beneficiaries participate in related trainings, workshops and seminars offered by GTZ program. GTZ will also explore the potential support and involvement of other German Research Organisations/Institutions.

The goal of the mission was, to support the GTZ initiative in implementing efficient natural waste water treatment systems with low energy and maintenance requirements.
The main target area of the mission was the CW Bayawan. Additionally general activities had to be performed to enhance the replication of the system in other places.

The scope of work was in detail:

- Supervision of the installation of the distribution pipes in Bed 1.
- Review of technical options for the distribution pump and distribution devices
- Assessment of the performance of Bed 2 and calibration. Bed 2 is being temporarily used as the only treatment step for the effluent from the septic tanks.
- Resource person for a workshop training on Operation and Maintenance of the WWTP. The workshop will be organized by GTZ. Goals of the workshop will be:
    - to inform the project team and the users about the O&M requirements of the WWTP,
    - to discuss and finalize the O&M Manual,
    - to set-up an O&M Team (including the option to finally devolve O&M to the users group)
- Finalization of the Operation & Maintenance Manual in cooperation with the local consultant, the project team and the future operators of the treatment facility.
- Pre-Design of a treatment concept for the sludge from the septic tanks, including reuse options for the treated sludge. Reuse options should be discussed in the context of Bayawan's efforts to improve agricultural productivity.
- Assessment and recommendations for future applications for constructed wetlands in Bayawan City; i.e. the bus terminal. (The City Engineers Office prepared already a draft.)
- Prepare a concept for the monitoring program, including laboratory equipment (mobile or permanent laboratory), the personnel requirements and the institutional set-up.

4 Measures and activities, including results

4.1 Constructed Wetland in Bayawan

State of construction and operation

Regarding the ***schedule of construction works***, there was a minor delay of the start-up of the wwtp. This is due to the following reasons:

- extraordinarily heavy rainfalls and the high ground water table during construction
- difficulties in material availability (pipes, pumps)
- high costs for the main pump.

The status in detail:

Currently 150 households with ***700 inhabitants are connected*** to the sewer system, which ends in the main pump sump

During the mission, the pump sump appeared to be already filled, so the waste water was applied to cell 2 as an ***interim solution*** until the routine operation will start (after development of the plants, about 6 weeks after transplanting) . As the pump was not installed yet, a mobile unit had to be used.

Flushing device

The **filter layer** in cell 1 could be completed during the mission. Even heavy rainfalls, prevailing during the mission, could easily pass the filter media. This indicates, that a suffficient permeability of the filter is given. A sample of the installed media will be tested additionally.

Header tank with distribution system

The design of the ***distribution system*** was changed prior to the mission. According to the detail planning, a high-volume pump was required for the equal distribution of the waste water within a short time. Due to the high costs for such a pump the design was altered. Instead, four distribution tanks will be filled simultaneously by a small pump. From there by an automatic mechanical device, the water is flushed into four similar distribution pipe systems. The division of the surface area was necessary, because, for equal distribution, a big volume of water has to be flushed within short time. One of these systems has been installed and calibrated.

Calibrating the distribution system

Each tank has the capacity of 14 cbm. The water will continuously be pumped by a 5 hp-pump from the main

sump to the tanks. From the storage section of the tank the water flows into a separate chamber, where the mechanical flushing device is installed. This device releases the water via an 8” (200 mm) pipe into the distribution pipe network of 2” (50mm) pipes laid parallel in 2, 37 m distance with drilled holes (6 mm) in 2 m distance, which results in roughly one hole per every 4,7 sqm of surface area.

The other identical distribution systems still remain to be installed. The mechanical flushing device had to be purchased in Germany just before the mission, to allow for a completion of this major engineering task during the mission. For construction of the other tanks, other options have been discussed (as the operation will be done by a full-time worker, the water release can be done manually, using e.g. a backflow barrier valve). Thus, an expensive and administratively complicated import could be avoided.

Bed 2: good development of the plants

The distribution pipe on cell 2 could be almost completed during the mission

The ***plants*** left for cell 1 are growing well in the nursery and are ready for transplanting.

The ***pumps*** for the main sump could not be installed during the mission, but are already defined and ordered and are supposed to be installed in the meantime.

In the ***outflow chamber*** an overflow had been installed, which leads to the surrounding area. During the mission the construction of a trench below the highway (which is under construction) was started, which leads to the sea. The flexible pipes, currently installed, should be replaced against bigger ones, to allow for a good rainwater drain.

Waste Water Volume & Quality

Still, the waste water volume, produced by each inhabitant, is not yet fully determined. A first rapid assessment (basing on water consumption data for May 2006, assuming 6 P.E./household) resulted in 50 L/(P.E.*day).

A first analytical assessment of the inflow quality was performed during the mission. The analyses (sampling date 27th June; main pump sump) have been performed in the Silliman University. The results are as follows:

Parameter		**Unit**	**Value**
Total suspended solids	TSS		20.1
Biochemical Oxygen Demand	BOD_5	MgIL O_2	7.0
Chemical Oxygen Demand	COD	MgIL O_2	< 5.0
Ammonia		MgIL NH_3-N	< 0.1
Nitrate		Mg/L NO_3-N	0.06
Ortho-Phosphate		MgIL PO_4-P	0.14

The results look more like effluent concentrations than waste water from the inflow, especially the Ammonia, BOD, COD and Phosphate concentrations. The time between the sample delivery to Silliman and the date, when the results were delivered was more than three times longer than necessary for a proper (BOD-) analysis. That indicates that the results might have been subject to biochemical degradation during the storage. Another explanation can only be a fault in sample marking at the lab. A proper training respectively, supervision of the analytical procedures is necessary. It shows also the importance of installing the city lab as soon as possible.

Operation & Maintenance

The organizational aspects of the subject are given below.

For the latest version of the O & M manual see Appendix 3. The manual has been extended during the mission, to give a more detailed view into the working principles of the treatment plant. for the personnel involved. The operational parts of the manual will be translated into the local language.

Monitoring

According to information, provided by the City Engineering Department, there is funds of 1 million PHP already allocated for construction und equipment of a lab. The lab will be run by the LGU and is planned to be constructed at the treatment site.

A monitoring program proposal was given during the workshop and is part of the O & M manual (Appendix 3).

Organizational Structure

The organizational structure has been worked out during a workshop, held on June 27th. To cover all operational acitvities, four teams have been defined. Details are given in a separate report by Imelda R. Balbuena, GTZ Water Programme, Oriental Negros

4.2 City WWT concept

The LGU is planning two more CWs, one at the seaside and one at the new bus terminal. The locations for both plants are defined, but yet the basic design preconditions for the sea side facility and the financial aspects seem not in a state yet to allow for a proper pre-design. For the bus terminal already a rough design is supposed to be existing, but could not be evaluated during the mission.

Map of the WWTP – sites Bayawan

Concerning the sludge processing, the LGU has already a program for biogas production from the septic slugde. On the workshop the option of reed beds for sludge dewatering has been presented.

4.3 Dissemination activities

Brochure for the potential users

As additional task a brochure for potentional users has been compiled. Text and pictures for the brochure are given in Appendix 4. The layout has to be done locally.

Site visits

Since the groundbreaking ceremony several groups have been visiting the site. During the mission a visitor from the University of Western Mindanao, Zamboanga, was informed about the activities. The City of Zamboanga has a vital interest in solid waste and in waste water treatment solutions

5 Evaluation of the results, assessments and recommendations

5.1 Constructed Wetland in Bayawan

Construction and Operation

At the present state of information the successful complete implementation of the WWTP within a short time is very probable. A very important part of the know how transfer has already been done.

Because the final capacity ot the treatment plant is not totally known, the increase of loading has to be accompanied very thoroughly (“controlled approaching” the system limits – see below). Another German expert visit after the evaluation of the first performance data is recommended, to work out a schedule for controlled high load and quick response to the monitoring data. This visit should be combined with the dissemination of the technology to other possible users.

The Bayawan engineers and the city construction company proved to be able to perform the project in terms of organisation and qualification. There is a high degree of dedication to the task and loyalty to the community. The total project can be a good example for a successful implementation of a new technology. The treatment plant will serve as a demonstration site which attracts many visitors.

There is not much practical work left, to finish the treatment plant. The works, along with possible implementation time, in detail are:

- Installation of the distribution systems in the other three fields of cell 1 (July 2006)
- Installation of the small main feeder pumps (July, 2006)
- Finishing the distribution system of cell 2 (July, 2006)
- Installation of an overflow from the outflow tank, connected to the sea
- Planting cell 1 (July 2006)
- Starting routine operation (August 2006).

The connection of the sewer from the nearby high school is planned for the nearest future. This should be done as soon as the plant is in full operation and accustomed to the waste water (6 weeks after starting the full operation).

Operation & Maintenance

During the preparation process for O&M a certain lack in networking could be found. It would be helpful, if regular meetings would happen, supported by installation of an information network, e.g. by an email work-group system. Especially a short route between monitoring and the operation team is strongly recommended. This is especially important in phases, when additional batches of users are connected to the system.

As the capacity of the treatment system is not fully known and a “controlled approaching” the system limits is part of the strategy, the O&M team must be able for a fast reaction on monitoring data.

Regarding the organizational chart the O & M manual has to be completed by the city government.

Monitoring

The water consumption can be measured easily, because of the water meters supplied for each consumer. Still the real number of people living in each household, is not known. This aspect should be assessed precisely. Concerning the final number of the households and inhabitants there are still varying information.

The budget allocated for the purchase of the lab equipment and the building is 1 Million PHP. In the O&M manual the parameters of interest are listed. Additionally to the water consumption, the amount of water, pumped by the main pump into the distribution tanks should be measured. This can be done by recording the operation time of the pump. As an alternative, also the start incidents of the pump can be recorded and multiplied by the volume pumped each time, which is given by the level switch settings.

The monitoring/analytical work has to be done by a trained person, employed by the city. The director of the Bayawan Water District, Mrs. Alma Abrasaldo, offered to perform the interim monitoring, until the city lab is in operation, and to train the lab personnel. This generous offer should be taken into account.

To ensure a quick and cost effective start-up of the monitoring, it is recommended, to purchase the equipment as soon as possible and put it into interim operation until the lab building is constructed. This is especially important under the aspect, that the analyses at Silliman University in Dumaguete are relatively expensive and require special transportation.

As the lab of the water district is currently under renovation, there could be space for the interim operation of the equipment. Once the new building is installed, the equipment could be transferred.

Organizational Structure

Still, the role of the Community Relation team is not totally clear. Also the position of the overall co-ordinator should be reconsidered. If co-ordinating the operation teams and the control task of the PCO are located at the same desk, conflicts of interest could arise. Instead, the role of the PCO should be, to decide, if the discharge quality meets the national standard and to address the overall co-ordinator, if the effluent quality exceeds the standard. The co-ordinator in turn then has to co-ordinate the upgrade of the treatment process.

To fully elaborate the responsibilities of the teams, a follow-up of the workshop was considered to be necessary.

5.2 City WWT concept

As there was no opportunity during the mission, to discuss the existing data and designs, it is proposed, to use the internet work group for discussion of the projects.

Appendix 1: Daily summary of the activities

Sa. 17.06.:	Departure Belzig 04:00; Arrival Manila 18.06., 08:00; arrival Dumaguete 17:00
Mo 18.06:	Briefing in the GTZ-office Dumaguete, transfer to Begawan; site visit; meeting city eng.; courtesy call mayor
Tu. 19.06:	Material selection at the construction site; working on the O&M manual; site supervision distribution tanks
We. 20.06:	site supervision distribution pipe layout; preparation work for the O&M workshop
Th. 21.06.	site supervision pipe layout; meeting with head of water district; discussion of analytic program; emptying outflow tank cell 2
Fr. 22.06.	site supervision; first application of waste water to cell 2; meeting with Prof. Fonallara, Univ. Western Mindanao; discussion of waste and waste water treatment and recycling options in Zamboanga City
Sa. 24.06.	preparation of the information brochure on constructed wetlands
Su. 25.06.	Report ; 0&M manual; transfer to Bayawan
Mo. 26.06.	site supervision; final calibration of the distribution system
Tu. 27.06:	O&M Workshop with site visit; final discussion with the operational team in Bayawan; transfer to Dumaguete
We. 28.06.:	Final report GTZ office Dumaguete; final planning session with the local consultant
Th. 29.06.:	Final report GTZ HQ Manila
Fr. 30.06.:	Departure, Arrival Belzig 23:00

Appendix 2 Contacted persons

Vincent Delector, GTZ Bohol
Michael S. Mananquil, City Engineer Bayawan
Saturnino S. Cabanban, Jr.,Planning Officer Bayawan (project manager reed bed system)
Imelda Balbuena GTZ, Communty Organizer
Alma Abrasaldo, Director Bayawan Water District
German P. Sarana, Mayor of Bayawan
Marchita P. Fuale, City Planning Officer, Bayawan (social aspects of the project)
Eric O. Torres, F.E.
Sheila Torrille, Admin. Officer (assistant of the city engineer)
Mark Tom Q. Mulingbayan, environmantal consultant
Ulrike Lipkow, Program Adviser, GTZ office Dumaguete
Andreas Kanzler, GTZ Program Director, Water Sanitation, Solid Waste
Prof. Dr. Vivian Fonallara, Western Mindanao University
Claudia Wölk, GTZ Manila

Gawad Kalinga Fishermen's Village Constructed Treatment Wetlands

Brgy. Villareal, Bayawan City, Oriental Negros

Wetlands Operation & Maintenance Manual

(Draft 21 June 2006)

Prepared for GTZ and Bayawan City by

Joachim Niklas
Mark Tom Mulingbayan

Abbreviations

BOD_5	Biochemical Oxygen Demand (corresponds to the concentration of soluble biodegradable organic substances)
COD	Chemical Oxygen Demand
CW	Constructed Wetland
DAO	Department Administrative Order
DENR	Department of Environment and Natural Resources
ECC	Environmental Compliance Certificate
EMB	Environmental Management Bureau
LGU	Local Government Unit
O&M	Operation and Maintenance
PCO	Pollution Control Officer
P.E.	Population Equivalent
SS	Suspended Solids
WWT	Waste Water Treatment
WWTP	Waste Water Treatment Plant

Table of Contents

General Project Information

The Gawad Kalinga Fisherman's Village is a relocation project of the local government of the City of Bayawan for the informal coastal settlers who will be displaced by the coastal road project. A seven-hectare property in Brgy. Villareal has been acquired for the relocation project that will house more than 700 families.

In compliance with the provisions of the Clean Water Act (Republic Act 9275) and the conditions set forth in the Environmental Compliance Certificate (ECC) issued by the DENR, a low-cost sewage collection and treatment facility is developed within the relocation site.

With technical assistance from the German Technical Cooperation Agency (GTZ), the local government has constructed a low-cost low-maintenance natural wastewater treatment system using constructed wetlands, in addition to a primary treatment and collection system composed of onsite septic tanks shared by household clusters.

Organizational Setup

Teams involved in the constructed treatment wetlands project:

- Overall Wetlands Project Coordinator (Aguilar/PCO?)
- Field operations team (Aguilar/PCO)
- Engineering and maintenance team (Cabanban or Mananquil/Engg)
- Community relations team (Lito/Engg)
- Water quality monitoring team (Alma/BAWAD)
- GTZ Role?

The members of the various teams associated with the wastewater treatment facility shall be adequately trained for their particular function.

[INSERT HERE BAYAWAN'S PROPOSED ORGANIZATIONAL CHART]

General Overview of Constructed Treatment Wetlands Technology

A constructed wetland is a man-made marsh, sealed to the subsoil and planted with aquatic plants like reeds. In the past few decades, the use of constructed treatment wetlands for water quality improvement has been gaining popularity in communities requiring low-cost, low-maintenance systems. Taking advantage of natural treatment processes but engineered to maximize efficiency, constructed treatment wetlands are capable of reducing pollutant loads in wastewater to levels that can satisfy local water quality standards. In addition, these systems also present ancillary benefits such ash enhancing the aesthetic of a locality and providing wildlife refuge, resulting in a generally good reception by the public towards the technology.

In a wetland system the water treatment is achieved by different factors:

- the media (soil, sand or gravel), which serves as a filter and absorbs contaminants
- wetland plants, which supply oxygen to the media and take up nutrients to a certain extent
- microorganisms, which are responsible for the breakdown of the contaminants.

The treatment efficiency is mainly due to the microbial activity. The microbial activity increases with the surface area to be covered by the microbial biofilm. Thus the treatment performance is better in soil filter systems compared to open water bodies or gravel beds, because the growth surface for the bacteria is higher there. Fine material performs better than coarse material, but it must not be too fine, because otherwise the infiltration is not fast enough. The Bayawan treatment facility is a combination of two types of wetland systems:

1. Vertical soil filter (cell 1)

In the vertical systems the waste water is applied on the surface of the soil filter. By the infiltration process air is sucked into the pores of the filter material, supplying oxygen for the bacteria, which are living as biofilm around the sand particles. This is the most important factor for the degradation process. So the cleaning effect is high with relatively low area requirement. By passing the filter layer, the water is treated not only by microbial activity, but also by adsorption processes. The extraction and later decomposition of persistent organic compounds is best in this system as well as the removal of pathogens. The challenge of this system is the rapid and even distribution of a high amount of water. This requires a big pump or a big tank above the surface of the filter bed.

2. Horizontal soil filter (cell 2)

The water flows horizontally through a gravel or sand bed of 0.4 to 0.6 m thickness, which is planted with helophytes (marsh plants). The microbial growth takes place on the surface of the gravel and the plant roots. The plants supply some oxygen by their roots, which is used by the micro organisms for aerobic breakdown of the contaminants. Due to the plant roots as only means for oxygen supply, the aeration is not as good, as in the vertical system. So the performance is limited relatively. The area requirements for a given performance are higher compared to the vertical systems. However, the advantage is that the water can be applied continuously without using a pump or a mechanical flushing device.

The combination of two cells improves the water quality especially with regard to the hygienic quality. Every passage of a soil filter reduces the amount of faecal indicator organisms by the factor of almost 1000.

In general, constructed wetlands do not require large energy and chemical inputs and demand no specialized technical expertise to operate and maintain, as compared to conventional wastewater treatment systems. However, natural treatment systems commonly involve large area requirements and large capital outlays, making it relatively unsuitable for highly urbanized communities where real estate is at a premium.

Constructed wetlands were originally simple ponds with aquatic plants in them, but as research on the capacity of plants to improve water quality progressed in the search for higher pollutant removal efficiencies, state of the art constructed wetlands design evolved from free water surface systems to subsurface flow systems to highly engineered subsurface flow wetlands. The Bayawan constructed wetlands belong to the latter type, which means high removal efficiencies can be expected in a relatively smaller area.

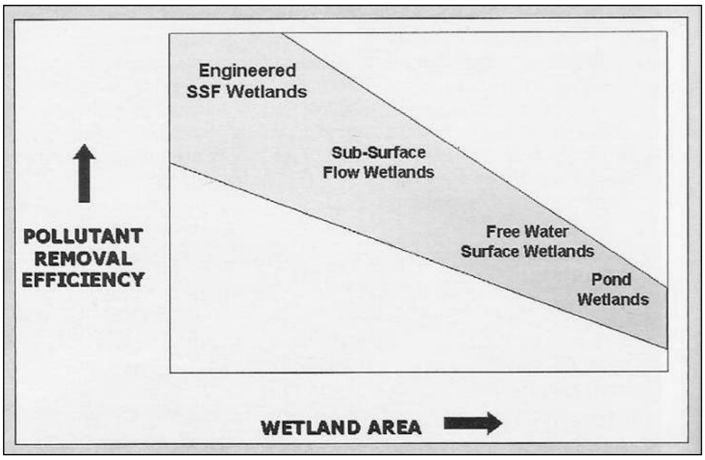


Fig. 1. Different wetland types and their comparative efficiencies and area requirements

Description of the Bayawan Constructed Treatment Wetlands

In compliance with the Clean Water Act, a wastewater treatment facility is established for The Gawad Kalinga Fishermen's Village, consisting of a primary treatment and collection system and a set of constructed treatment wetlands.

The primary treatment system is composed of several onsite three-chambered septic tanks shared by household clusters and are distributed across the entire area of the village. Fresh sewage originating from the toilets, showers and kitchen sinks of the houses are partially treated in the septic tanks, reducing the biochemical oxygen demand (BOD) and solids content. The overflow from these septic tanks are collected by gravity through pipes to a main sump for storage and further solids removal. From the main sump, the wastewater, already free from suspended solids, is fed to a series of two constructed wetland cells planted with the local variety of reeds (scientific name *Phragmites spp*, locally known as *tambo*).

Influent from the main sump is pumped to several smaller header tanks that are connected to a network of distribution pipes deployed across Wetland Cell No. 1. The first wetland cell is a vertical subsurface flow wetland system wherein the influent is distributed across the area and the wastewater allowed to infiltrate the surface and percolate down the root-sand media of the wetland, collected at the bottom layer of the bed by a network of perforated pipes which discharge into a small sump at one corner of the wetland cell. From this sump, the wastewater is transferred by gravity to Wetland Cell No. 2, a subsurface horizontal flow system which can also be operated as a hybrid vertical/horizontal flow system when the volumes of wastewater are high. The effluent of the second cell is collected in another small sump from which the treated wastewater may be either reused for irrigation purposed, disposed of in a nearby sea outfall or recirculated back to the wetlands for further polishing or as makeup water in cases of low flow.

Design Parameters and Assumptions

The septic tanks were primarily designed by the Engineering Office of the City of Bayawan, and the wetland treatment system was designed for the city by experts provided by the German Technical Cooperation Agency.

The wetland designed was based on the assumption that the village will be composed of 700 households with an average of 5 members per family. Per capita generation of wastewater was assumed at 50 liters per day. It was recognized from an early stage that the village will be completely occupied a few years after the completion of the wastewater treatment system, but there are plans by the local government to feed wastewaters from other nearby sources while the estimated design flow rate is not yet attained. The following table presents the basic parameters considered for the design of the wetlands:

Table 1. Basic Design Assumptions for Bayawan Wetlands*

No. of households	738
Persons per household	5
Total population at full occupancy	3,690
Per capita WW generation rate	50 L/cap/day
Total WW generation flow rate	184.5 m^3/day
Design hydraulic loading	50 L/Pop.equiv.
BOD concentration	300 mg/L
Total BOD load	55.35 kg/day
Area of Cell 1	1,800 m^2
Area of Cell 2	880 m^2
Area per population equivalent	1 m^2
Hydraulic Load	102.5 L/m^2
BOD Load	30.7 g/m^2

*Adapted from Niklas, J. Short Term Expert Report for GTZ dated March 2005; with some modified/updated figures as of 21 June 2006.

From previous experiences in vertical flow constructed wetlands in Asia, a BOD loading of 103 g/m^2 and hydraulic loading of 149 L/m^2 for wastewaters of initial BOD concentration of 766 mg/L can reduce the pollution down to 20 mg/L. Since Bayawan enjoys a relatively stable, narrow tropical temperature range year round, actual loads exceeding the design assumptions are not expected to seriously hamper the pollutant removal performance of the system. At any rate, a provision for recirculation and/or changing the flow regimen in the second wetland cell should be able to address any loading shocks or unexpected peaks in the quality of the treated effluent.

Wastewater Collection and Preliminary Treatment System

Fresh sewage originating from the households are collected in three-chambered septic tanks shared among 10 households. The volumetric capacity of the tanks are insufficient to remove all the dissolved organic pollutants in the water but can be reasonably expected to remove most suspended and floating solids from the sewage, if maintained properly by regular desludging. Because the bottoms are sealed for all three chambers, there is little risk of leaching into the groundwater table, although the probability is not zero, as concrete and masonry construction is not totally impermeable. The overflow from the septic tanks is partially treated sewage, loaded with a still significant amount of organic pollutants (measured by biochemical oxygen demand or BOD) and nutrients, and some minimal amount of suspended solids.

Table 2. Septic Tank Specifications

No. of chambers	3
Dimensions of each septic tank	2.4 m x 4.5 m x 2.0 m
Septic tank volumetric capacity	18 m^3
Expected retention time (at half cap.)	≥ 3.5 days
No. households sharing one septic tank	10

All partially treated sewage are collected in the main sump pit adjacent to the constructed wetlands, from which the influent for the first wetland cell is transferred by pump to the header tanks. The volumetric capacity of the main sump is around 40 m^3. It is covered by a concrete slab to minimize the escape of foul odors.

Wetland Cell 1

Wetland Cell 1 is a 1,800 square meter cell of concrete hollow block construction, sealed with elastomeric paint. The wetland media in which the reeds are planted is primarily sand, with a network of perforated collection pipes in the bottom surrounded by gravel. The minimum depth of the bed, including 0.6 m of freeboard, is 0.60 m.

The surface of the cell is divided into four sub-cells of more or less equal area, separated by low bunds made of sand. There are five parallel perforated distribution pipes in each sub-cell, fed from one header tank (per sub-cell) by gravity with a head of not more than 1m. A flushing mechanism is installed within the header tank that will control the flows into the distribution pipes. The end of the distribution pipes can be accessed at the perimeter of the wetland cell for maintenance.

The collection system at the bottom of the bed is composed of perforated PVC pipes covered in gravel, all discharging into the outlet sump. The ends of the perforated pipes are extended into the atmosphere, at one side of the cell, for flushing in case of clogging, and to prevent vacuum conditions at the bottom layer.

The outlet sump of Wetland Cell 1 is connected to the inlet works of Wetland Cell 2.

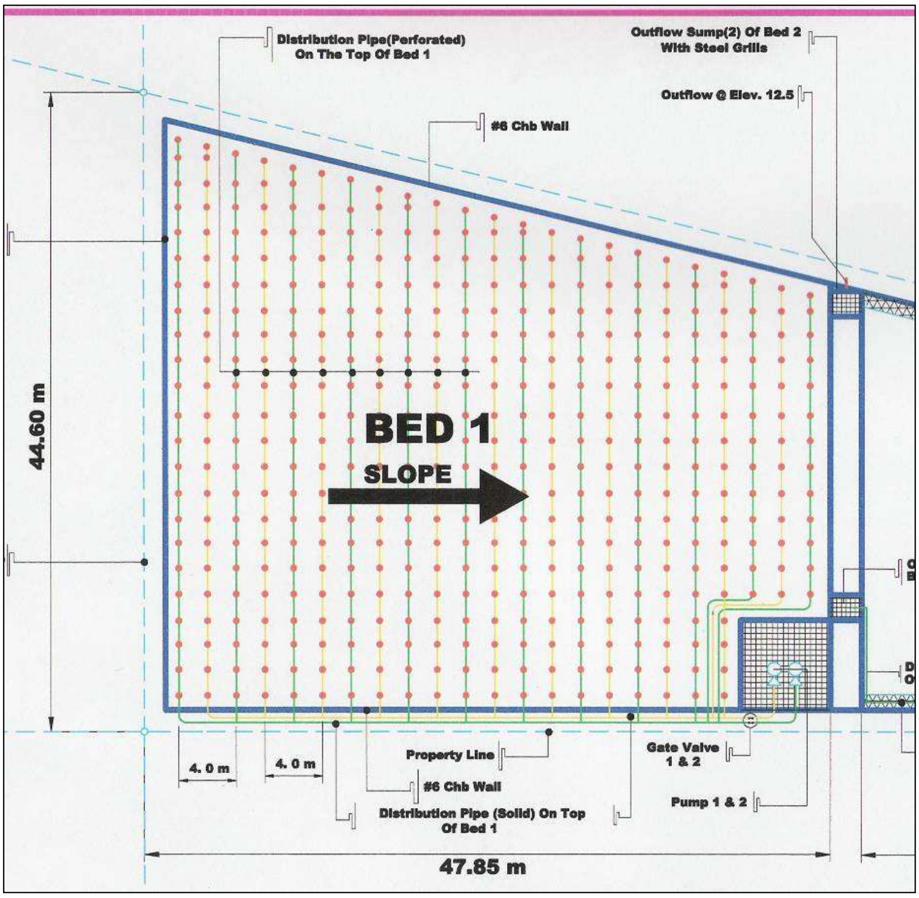


Fig. 2. Wetland Cell 1 – Influent Distribution System (original plan)

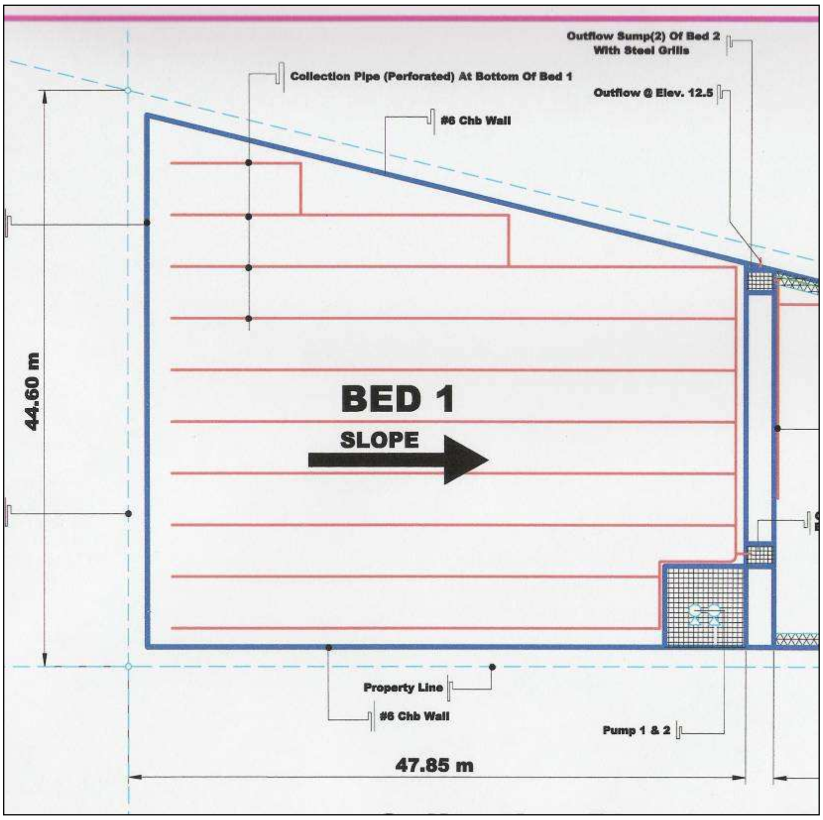


Fig. 3. Wetland Cell 2 – Effluent Collection System (original plan)

Wetland Cell 2

Wetland Cell 2 is an 880 m^2 cell of concrete hollow block construction, sealed with elastomeric paint. The wetland media in which the reeds are planted is primarily sand. The elevation of the surface of the reed bed media is slightly lower than the outlet pipe of Wetland Cell 1, therefore the effluent of the first cell can be fed to the second by gravity. Along one side of the second cell is a one-meter wide strip of large rock which comprises the inlet works. On the other side of the bed is a similar strip of rocks which serves as the outlet area. There are two configurations for the outlet works. For the horizontal flow option, the rock gabions at the outlet has an opening towards the outlet sump with a flexible hose whose opening can be modified in elevation. For the hybrid vertical-horizontal flow option, a set of perforated pipes were placed at half of the bottom of the bed, designed to collected percolated wastewaters through the sand media. These perforated pipes are extended to the atmosphere, installed with cleanouts at the end to serve as access for maintenance of the interior of the pipes. These pipes also discharge into the same outlet sump. The depth of the bed, including about a meter of freeboard, ranges from 0.6 m to 0.9 m.

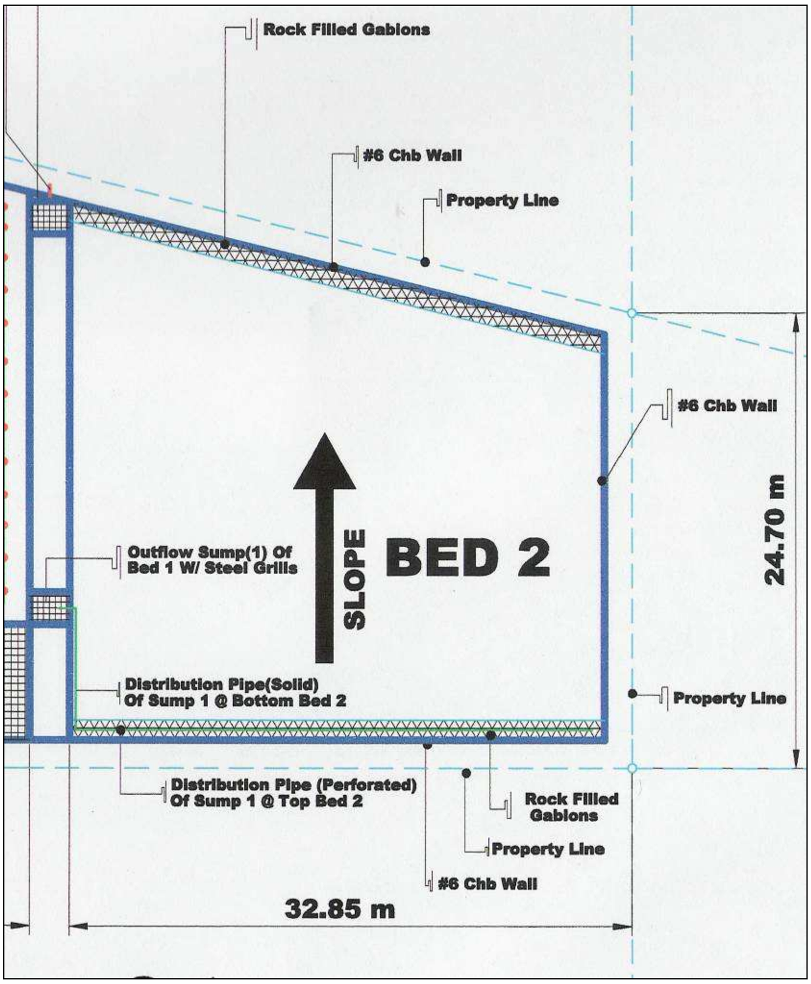


Fig. 4. Wetland Cell 2 - Influent Distribution System (original plan)

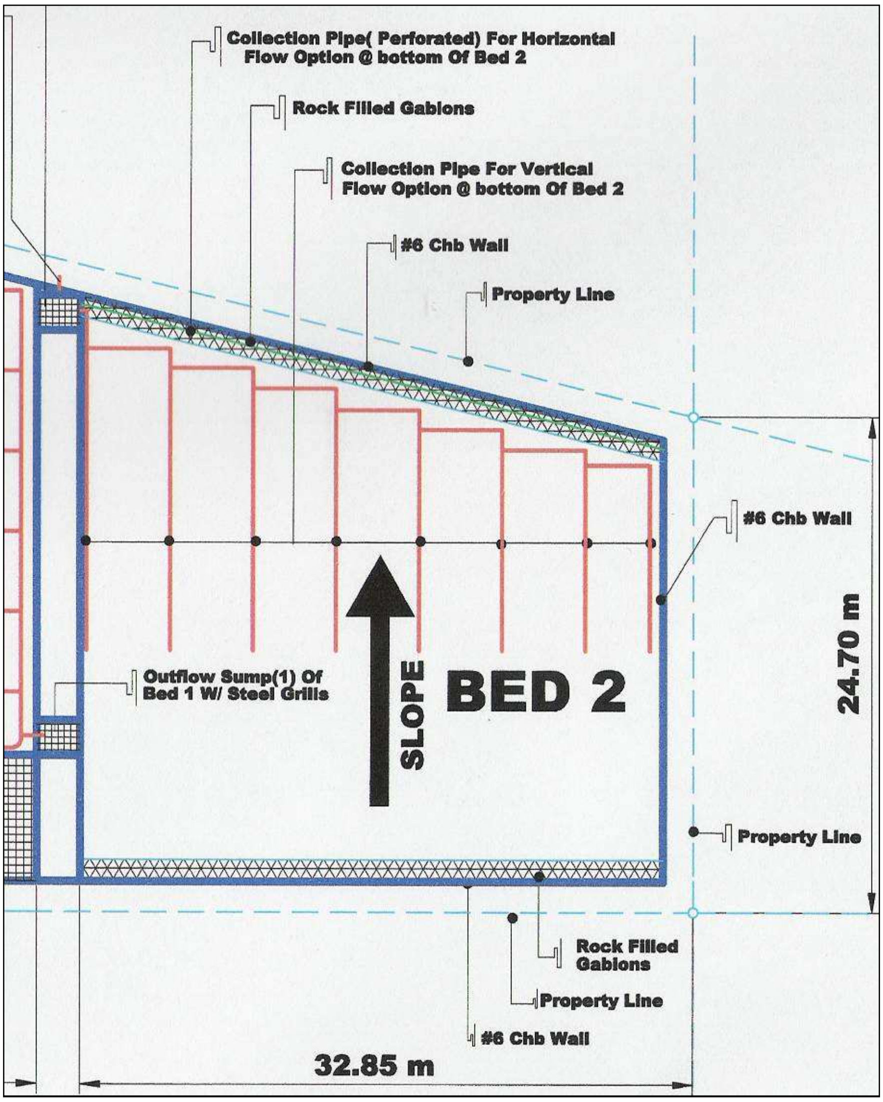


Fig. 5. Wetland Cell 2 – Effluent Collection System (original plan)

Operational Procedures

Main Sump

The collection of partially treated sewage from the septic tanks are collected by gravity in the main sump. Because the presence of high concentrations of suspended solids could potentially clog up the wetland media leading to flow short-circuit and reducing the pollutant removal efficiency of the wetlands, regular maintenance of the household septic tanks, collection pipes and the main sump pit itself is essential. This is done by regular desludging and removal of scum on the water surface. Take note however, that during desludging, a thin layer of sludge (composed of microorganisms that work to degrade the wastes) must be left in the tanks to serve as inoculant. The main sump has to be monitored monthly for solids inflow, even if the level switches are functioning.

In the sumps and septic tanks, dangerous gases can arise. These gases, such as methane, often have high density than air (i.e. they do not easily disperse from inside chambers) and are odorless so they cannot be easily detected. Control and maintenance work should be performed under safety precautions, for example utilizing two personnel, keeping the work space well lit and well ventilated or aerated. Open flames must be avoided as only 5% of methane in the atmosphere can cause an explosion.

Scum and Sludge Management

Sludge treatment is not the subject of this manual. However, general aspects should be mentioned:

Whether the sludge comes out of a biogas plant (which reduces odor emissions and produces energy) or from the septic tanks directly, composting is favorable to allow for a safe reuse under hygienic aspects.

The composting can be done in composting drums, on heaps/windrows, which are regularly turned over, or in drying/composting beds. The latter is an interesting option, which has the following advantages compared to the conventional drying beds: the converted sludge has to be removed only after more than 5 years, the material is odor free and has a high hygienic and fertilizer quality. The area requirement is only about 1 m^2 for 6 households.

Another option is to treat the sludge from septic tanks in a centralized anaerobic digester facility. An added advantage to this method is the production of significant amounts of biogas or methane which has economic value. The anaerobic sludge generated is relatively less in quantity compared to that of an aerobic system. However, it must be realized that the operation of an anaerobic treatment system requires constant (daily) monitoring of pH and volatile fatty acids – otherwise, a facility not well managed could lead to foul ups, producing undesirable odors and reduced removal efficiency.

Hydraulic Loading of Wetland Cell 1

Wetland Cell 1 is a purely vertical flow constructed wetland system, i.e., all influent is distributed evenly and intermittently (not continuously) across the surface of the bed, allowing the wastewater to infiltrate the surface and percolate down to the bottom in which perforated collection pipes convey the treated water to the outlet sump.

Because the cell is divided into four areas and each provided with its own header tank, influent feeding in one sub-cell can be independent of that of the others. This is advantageous when there is limited influent available so only one or a few sub-cells are used at one time (feeding by rotation), or when one sub-cell needs maintenance work and the others can keep on operating.

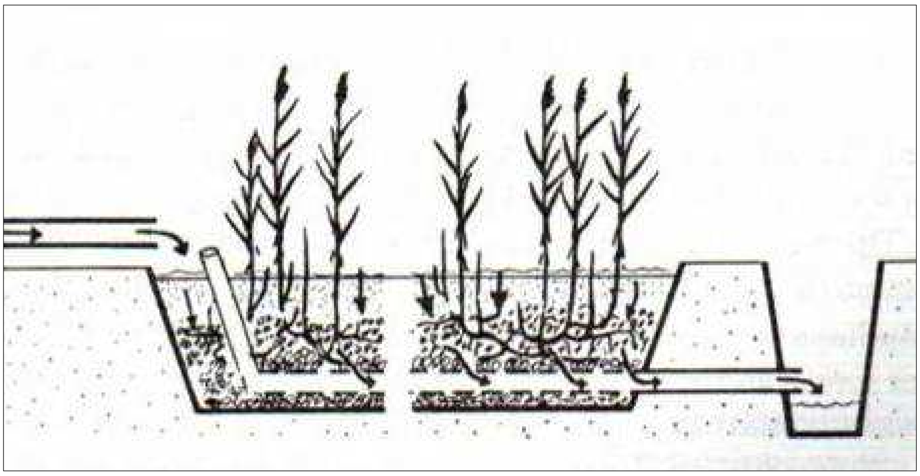


Fig. 6. Flow diagram of wastewater through a vertical subsurface flow system (image from Moshiri, ed. Constructed Wetlands for Water Quality Improvement)

Hydraulic Loading of Wetland Cell 2

Wetland Cell 2 is a hybrid horizontal flow constructed wetland. It is designed to function either as a purely horizontal flow system, or as a hybrid vertical-horizontal flow system. The changes in flow regimen can be controlled using two different outlet configurations. At any time, only one of the two outlet configurations should be used.

In the purely horizontal flow option, the effluent of Wetland Cell 1 is fed to the inlet works by gravity and the water allowed to travel across to the other side of the bed where the outlet works are located. Being a totally subsurface flow system, the movement of water across the bed is not visible on the surface. Movement is made possible by the existence of a slope in the groundwater table, that is, the water surface elevation at the inlet is higher than that at the outlet. The greater the level difference, the faster the velocity of the water will be. The water level at the outlet works is controlled by changing the elevation of the end of the flexible hose in the outlet sump.

In the hybrid vertical-horizontal flow option, the influent is fed in the same manner as that of the purely horizontal flow, but the treated wastewater is collected not at the outlet gabions but by the perforated pipes at the bed bottom. This collection system also uses the same outlet sump as in the horizontal flow option.

It must be stressed that whatever flow option is chosen, the outlet works for the other option must be closed or sealed.

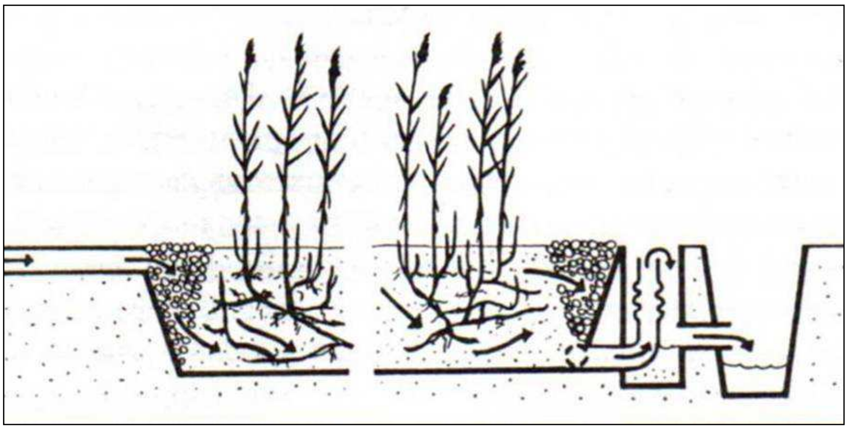


Fig. 7. Flow diagram of wastewater through a horizontal subsurface flow system (image from Moshiri, ed. Constructed Wetlands for Water Quality Improvement)

Recirculation

Recirculation means returning the treated effluent to an inlet within the treatment facility, whether partial flow or in full. Typically, there are two instances when recirculation is necessary. First, when there is not enough quantity of influent entering the wetlands, treated effluent may be used as make up water to satisfy the requirements of the plants. It must be always remembered that constructed wetlands are systems consisting of living organisms and sufficient water supply is vital. Second, should the final effluent quality not satisfy the effluent standards, for whatever reason, the treated water could be returned to either the inlet of Cell 1 or Cell 2 for further polishing. Also, adding mostly treated wastewater to the original wastewater stream dilutes the pollution entering the system.

Reuse

The most environment-friendly way to address the treated effluent coming from the outlets of Wetland Cell 2 is to re-use the water instead of discharging it in the nearest receiving body of water. Treated effluent obviously cannot be used for drinking water but other possible uses are for garden or agricultural irrigation, construction watering, or as flush water, provided that the water quality is satisfactory and sufficient additional plumbing in the village is provided.

Bypass

There may be instances during the life of the constructed wetland when the inflows may have to be bypassed from the system as a whole, or by part. For example, if one or both cells need to be serviced, the influent may need to be disposed directly to the final outfall or transported to another treatment facility instead of passing through the wetland system. Provisions for bypass may need to be installed at all inlet points.

Maintenance

Mechanical and Electrical Works

Maintenance work on mechanical and electrical equipment shall be performed annually, or at the frequency recommended by the equipment manufacturer.

The maintenance of the lift pumps has to be performed according to the instructions of the manufacturer. It must be noted that what flows inside the pipes and pumps are not clean water. The pH may not be neutral and it can potentially corrode unprotected parts. Solids accretion or slime accumulation inside pipes and on other equipment parts, if left unchecked and unattended to, may reduce their flowrate capacity.

Electrical and mechanical devices shall be serviced in accordance with the manufacturer's instructions. During maintenance work at the electrical equipment, the connections should be switched off.

Pipe Works

The distribution and collection pipes have to be monitored for blocking of the openings in six month intervals. In case of blockage, the end covers (cleanouts) of the pipes should be opened one by one. The blocking particles are flushed out using pressurized water, such as from a fire hose.

Check that all ventilation points are free of obstruction. Typical obstructing material are plant biomass (decaying leaves, rhizomes, stems).

Plant (Reeds) Startup and Management

During the establishment of the reeds weeds can be a problem. In horizontal systems, weed control is achieved by raising the water level of the bed above the surface for a period of about two weeks with a water table 5 cm above the surface, the more sensitive species will have gone. Alternatively, manual removal may be resorted to.

In vertical systems, weeds are usually removed carefully by hand. Reed growth is normally rapid, with full heights attained within a few months. The natural cycle of reed growth requires no human intervention. However, if some of the reed has been damaged or has died some action may be needed. In some locations the reed may be harvested by cutting. Harvesting is not detrimental to the reed and may improve the quality of the bed as any dead reed or detritus will be removed during cutting.

Aboveground growth removal also reduces the water requirement of the plants. Thus, the difference between the influent flowrate and effluent flowrate will be lessened. This water “savings” is significant if wastewater recirculation is a priority, especially when the wastewater supply is not sufficient. However, it must be ensured that prior to biomass removal, the root system is already extensive and well established.

The plant population has to be monitored regularly. Undesired plants have to be removed only if there is an obvious reduction in the reed population.

If the plants show discoloring and decaying parts are detected, the reason has to be looked for, to prevent further damage. The possible reasons and corrective action to be taken are presented in the following table.

Table 3. When the plants look stressed

Reason	Action to be taken
Harmful substances are in the water	Check the raw sewage If a portion of the plants has died by a single event, they have to be replanted. If necessary, soil and water analyses have to be performed.
The water supply is insufficient	Install a backflow from the outflow chamber into the pumping chamber, for recirculation. Use make-up water or wastewater from other sources
Reeds are damaged by animals/pests	Keep out grazing animals by fencing, especially during the reed coloniza-tion/growth stage Insect nuisances are normally no prob-lem; in case of heavy damage contact the consultant in charge before using pesticides. Insecticide residues could be washed down to the bed during rains, and could end up in the treated effluent.

It must be noted that in the course of the life cycle of plants, die-out of parts such as leaves and culms is a natural occurrence. There is no need to collect plant detritus accumulating on the bed surface.

Special consideration must be made of the invasive nature of *Phragmites*. Even if it is locally available in the margins of freshwater bodies, its spread must not be tolerated especially in rice fields and irrigation ditches. Reeds develop an extensive root network and are difficult to remove. Mere cutting or burning of aboveground growth will not work as the underlying roots will develop shoots in a short period. Complete removal of reeds require the removal of the entire root system which can reach as deep as 2 m below the surface.

Since the reeds are contained in a concrete structure, colony expansion by rhizomes is not expected. However, the wetlands operations crew must be made aware that disposal of reed rhizomes or cuttings outside the beds need to be done properly.

In the last quarter of the year, reeds typically produce flowerheads which last until the first quarter. The seeds produced require a very specific environmental condition to germinate and are thus not typically viable. Reed populations typically are spread by cuttings and rhizomes. Because the flowerheads have economic value (e.g. as *walis tambo*), the harvesting of these parts of the reeds may be allowed, provided that the plants themselves aren't completely harvested.

Monitoring

Record Keeping of Maintenance Work and Daily Operations

The office in charge of collecting and maintaining all records pertinent to the operations, maintenance and monitoring of the wetlands facility shall be the Pollution Control Officer (PCO) of the city.

A daily record of operations shall be kept, in which the periodic controls are proven and in which irregularities and special observations are recorded. Observed faults and accidents have to be registered in the record and, if necessary, reported to higher authorities.

All maintenance records on equipment shall also be maintained at the office of the city engineer. The PCO shall be periodically provided a condensed copy of such records.

Reed Bed Monitoring

The soil filter has to be checked for water on the surface regularly. Water on the surface can have the following reasons and corresponding countermeasures:

Table 4. When there is water on the surface

Reason	Action to be taken
The level in the outflow shaft is too high	Lower the water level at the outlet Reduce the application area to 50% for two weeks, to allow for drying out of part of the area; by natural mineralization of the organic deposits, the infiltration of the water will be facilitated quickly
Surface is clogged by sludge components from an insufficient pre-treatment	Check if sludge removal had been performed according to the regular schedule; if necessary, adjust the intervals Check the outflows of the septic tanks
The outflow drainage pipes are blocked	Clean the pipes by inserting a pressure hose with cleaning head via the vent pipes / cleanouts

In any case, the reason for surface water tracking has to be eliminated immediately as this reduces the pollutant removal efficiency due to short-circuiting

If clogging phenomena are to be seen (detectable by a dark layer on the surface of the filter bed, or surface tracking), the filter bed is to be operated only on one half of the surface, to allow for mineralization of the organics on the dry part. The reduction of the area is done by valves in the main pipes. After a duration of two weeks the other area has to be kept dry. After another two weeks, the total surface area can be used again for application of waste water.

The distribution pipes have to be monitored for blocking of the openings in half year intervals. In case of blockage, the end covers (cleanouts) of the pipes should be opened one by one. The blocking particles are flushed out.

Check that all ventilation points (at the cleanouts of submerged pipes) are free of obstruction.

Water Quality Monitoring

The main sampling points for water quality testing are: Main Sump (alternatively openings of distribution pipes during application), outlet works of Cell No. 1, and outlet works of Cell No. 2.

The minimum monitoring requirements are:

Table 5. Monitoring parameters

Sampling location	Parameter	Frequency
Main Sump	Influent Flow Rate	Weekly
	Dissolved Solids	Weekly
	Suspended Solids	Weekly
	BOD_5	Weekly
	Ammonia	Monthly
Cell No. 1 outflow	BOD_5	Weekly
	Ammonia	Monthly
Cell No. 2 outflow	Effluent Flow rate	Weekly
	BOD_5	Weekly
	Ammonia	Monthly
	Nitrates	Monthly
	Total Nitrogen	Monthly
	Orthophosphates	Monthly
	E. coli or faecal coliforms	Every two weeks

The duration of analysis for BOD_5 takes 5 days. An alternative monitoring parameter is Chemical Oxygen Demand (COD), the results of which can be reported within 3 hours after sampling and analysis. It is suggested that for the first six months of operations, both BOD_5 and COD analyses be performed for each effluent sample. In domestic wastewater, the ratio between BOD_5 and COD is a relatively stable value but needs to be determined. If, after six months, the BOD_5:COD ratio is verified to be more or less constant, only the COD test may be subsequently performed. The BOD_5 value may be estimated using the COD value and the established BOD_5:COD ratio. Actual testing for BOD_5 may still need to be performed at a frequency required by the DENR.

The local government shall provide a water quality testing facility, with adequate equipment and materials, where the analysis of the water samples will be performed. Adequately trained personnel shall be provided.

All sampling and analysis shall comply with the latest edition of Standard Methods for the Examination of Water and Wastewater (WEF/APHA/AWWA). However, for practical reasons, alternative test methods not sanctioned by the Standard Methods (e.g. test strips) may be used, provided that the use is only for internal process control, not regulatory purposes.

All wastewater analysis results shall be compiled at the office of the Pollution Control Officer of the city, with copies provided to the City ENRO, BAWAD and the GTZ Water Program. A periodic report (quarterly or semi-annually) on the wastewater treatment facility's performance shall be prepared by the PCO and provided to the Regional DENR Environmental Management Bureau office and the GTZ Water Program.

Community Involvement

Aside from the members of the community who will occupy important positions in the day to day operations of the facility, the other residents of the village also have a direct impact on the success of the constructed wetlands project, mainly in the quantity and quality of the raw sewage they generate. A continuous information, education and communication (IEC) campaign should be undertaken by the LGU to ensure that the community is using the wetlands facility properly. Because the quantity of water used in the household has a direct correlation with the volume of wastewater produced, excessive water use results in higher hydraulic demands on the wastewater treatment system. The quality of the raw sewage has a direct effect on the efficiency of the constructed wetlands. Constant monitoring on the types of household chemicals being used in the community is essential; in no instances shall deleterious substances be allowed to enter the wastewater stream. The table below presents a partial list of substances that may affect the wetlands facility.

Table 6. Partial list of household substances that may affect the constructed wetlands efficiency or need to be used responsibly to minimize environmental impact

Household product	Substance / chemical	Effect in the environment and in the wetlands
Detergents, soap	Surfactants	Foaming in the sump pits and distribution pipe perforations
Bleaching products (Zonrox, Chlorox)	Chlorine compounds	Inhibits microbial growth
Salt	Chlorides	High salinity in wastewater stresses the reeds and microbial action in the roots is slowed down
Oil and grease	Fats and lipids	Floats on top of water and prevents oxygen from being transferred to the water column Inhibits microbial growth
Hazardous chemicals, hazardous wastes, insecticides, herbicides, solvents	Heavy metals, toxic organics	Can kill the microbial population and the reeds

Substances with high nitrogen or phosphorus content are not necessarily undesirable for application in wetlands. In fact, these serve as fertilizers for the reeds which are voracious consumers of nutrients in water and may actually deplete the water and soil of these substances. In domestic wastewater, nutrients are generally always in sufficient quantity compared to industrial wastewaters.

A full scale campaign for the responsible use of household chemicals does not only have a beneficial effect on the wetlands performance. Changing people’s attitudes towards consumer products and resources eventually will help each individual to be aware of his or her impact on the environment.

Emergencies

Safety and accident preparedness. A safety and accident preparedness program shall be initiated by the local government. Regular drills shall be undertaken. General accident prevention measures in accordance with local and national regulations shall be observed.

Fire. A fire extinguisher should be kept ready at the site. For fire events associated with electrical equipment, act according to the local instructions. The most likely cause of fire is when dried plant material are ignited. In case of fire on the reed bed, operate the pumps manually to flood the surface of the filter bed. Fire trucks can be used to douse the fire, but seawater nor chemical foams should not be used. After the fire wait for one week. Replanting is only necessary, if resprouting does not happen. Reeds are a resilient species; even if the aboveground growth is removed either manually or by fire, the root system remains intact and new shoots should develop within a few weeks. Pollutant removal rates are not necessarily compromised, but effluent quality monitoring should be performed nonetheless.

Floods. In case of heavy rainfall, flooding of the surface area may occur. If the water level above the surface gets higher than 50 cm above the filter surface, the flood bypass pipe/valve should be opened. The valve should be closed after the water has disappeared from the filter surface. The operator should take extra precaution in monitoring and controlling the rate at which plant detritus on the surface is washed out; this can clog up the pipe.

Troubleshooting

Location	Problem	Possible Cause	Check or countermeasure
Main Sump	Solids to be found in influent	Turbulence in the water column	Install baffles in the sump pit
		Too much sludge accummulated in sump	Desludge the sump
	Foul odor	High BOD load in water	
		Presence of sulfur compounds such as H_2S	
Wetland Cells	Water or dark layer on surface	High solids content in the influent, clogging the wetland	Remove solids in sump
			Check SS in the influent
			Allow the solids to mineralize by stopping the feed and allowing more roots to grow
			Surface reduction for drying
		No water table slope (for horiz flow wetland)	Lower the level of outlet
		Clogged drainage pipes	Flush drainage pipes
Distribution pipes	Uneven flow distribution	Clogged pipe interior and perforations	Clean the pipes and perforations
Plants	Dying off or stressed	Inadequate flow	Increase water supply / hydraulic load
		Harmful substances in water	Check types of substances used in the households
		Not enough nutrients in the wastewater feed	Apply fertilizer in controlled quantities
Outflow	BOD > 20 mg/L or Ammonia-N > 5 mg/L Note: Clean Water Act standards are 50 mg/L for BOD and none for ammonia nitrogen	Influent BOD and ammonia too high	Check for likely source of sudden influent BOD peak
		Flow short circuit	Check for clogging, see
		Inadequate treatment	Recirculate flow

Operation Control Sheet
Constructed Wetland Fishermen´s Village

Week from ______________ to _______________ 200__

Daily Control (please, tick)**:**

	Mo	Tu	We	Th	Fr	Sa	Su
Visual control CW and pumps	☐	☐	☐	☐	☐	☐	☐

Weekly Control:

		yes	no
Filter bed	Water level o.k.?	☐	☐
	Dark suface layer ?	☐	☐

Monthly Control:

Septic tanks (ST)	Still water tight ?	☐	☐
	Sludge level: 50 % reached?	☐	☐
Main Sump	Inflow of solids from ST ?	☐	☐
Filter bed surface	Free water surface visible ?	☐	☐
	Vegetation unchanged ?	☐	☐
Distribution pipes	Even distribution ?	☐	☐
	Holes blocked ?	☐	☐
Outlets	Inflow of solids ?	☐	☐
	Outflow cloudy or with odours ?	☐	☐

Yearly Control:

ST and shafts	Lids of manholes ok ? Corrosion prevented ? Sludge layer in ST measured ? Electrical equipment checked ?	☐ **.... cm**	☐
Maintenance	Maintenance performed by skilled personnel/company ?	☐	☐

Remarks: ____

Date:_________ Operator:______________________________

Appendix 4: Brochure for possible users

Waste Water Treatment in Constructed Wetlands

- Information leaflet for the application of Constructed Wetlands on the Philippines -

Why waste water treatment ?

Waste water treatment is not a waste of money. There are different advantages connected with the treatment of waste water:

Health

The absence of treatment facilities for municipal sewage treatment all over the Philippines is the main reason for the prevalence of waterborne diseases. Due to contamination of the ground water resources by waste water infiltrating into the aquifers the drinking water quality is endangered and in some places already heavily reduced.

Madras, Anna University Campus

Environment

Also the environmental aspect is of great concern. For example the waste water outfall into the valuable coral reefs leads to changes in the biodiversity. This is also true for the open sweet water bodies.

Money

Latest publications show, that the Philippine economy loses more than 3 Billion Pesos annually due to water pollution, specifically on waterborne diseases. On the medium and long run the environmental degradation will effect also the tourism, which is an income source of increasing importance.

What is waste water ?

Waste water results from the use of drinking (or process) water in households, industry and other uses. This leaflet focuses on the household and municipal waste water. There the water pollutants are mainly of organic source: food residues, soaps and detergents and human urine and faeces. The waste water contains mainly organic solids, dissolved organic compounds, ammonia and phosphorus. Only, if special industries like metal processing enterprises are connected to the municipal sewer system, the waste water might be contaminated by toxic compounds.

The main pollutants are at the same time plant nutrients, which are needed in agriculture for soil improvement and fertilisation. The reuse of municipal sewage for irrigation and other purposes is possible, if toxic contamination by industries is avoided.

Why throw away wastewater *?*

Why call it wastewater at all, when it is loaded with valuable nutrients that need only be reclaimed and redistributed? We can extract the phosphorus and nitrogen to be used as fertiliser, and purify the "wastewater" until it is sparkling clean and ready for reuse.

How to *treat* waste water ?

For waste water treatment many different systems have been developed. The basic feature of all the systems is the supply of oxygen to the water. The oxygen is needed by the micro-organisms for the decomposition of the organic compounds and the conversion of ammonia into nitrogen. The micro-organisms settle on the surface of filling material in the treatment tanks or are floating in the water. The organics are broken down to carbon dioxide and water and the ammonia is oxidised into nitrate.

In specially sensitive situations the nitrate and phosphate have to be removed as well. The phosphate is usually removed by precipitation (under aerobic situations). The nitrate can be converted into gaseous nitrogen ("denitrification"), which is a natural component of the atmosphere, as well as carbon dioxide. The process of denitrification needs the absence of oxygen and the presence of dissolved organic compounds. This makes the procedure somewhat complicated and requires sophisticated process management.

The removal of the nutrients nitrogen and phosphorous is not desired, if the water is reused for irrigation. If reuse of the water is the treatment goal, or if the outfall flows into an open water course, which is used for the extraction of drinking water, the effluent has to be clean also under hygienic aspects. For the removal of bacteria and viruses the water has to be filtered and/or a long retention time in the treatment system is required.

What *kinds of treatment plants* do exist ?

There are many solutions for the treatment of waste water, technical and (semi-) natural systems:

Technical treatment plants

Activated Sludge Plant

The technical treatment process usually has three steps: mechanical pre-treatment for removal of solids, biological treatment, and final clarification. The biological step needs an artificial input of oxygen. The required tanks are relatively small and the retention time is short. Besides the most advanced technology, the membrane bio-reactors, they are not able to filter the water. Disinfection has to be done in an additional step by chlorinating or ultraviolet radiation. The energy requirement and the required maintenance skills are high.

The ***Trickling Filter*** is a cylindrical tank is filled with rocks. The waste water is distributed on top of the rocks. By dripping downwards, the water is enriched with oxygen and is cleaned by passing the microbial biofilm on the rocks. This is one of the oldest technical treatment systems, with the least requirements, concerning the operation and maintenance skills.

In the ***Activated Sludge Plant*** the water is treated in a tank by bubbling air into the water. A permanent movement is needed, to keep the floating micro-organisms in contact with the water contaminants.

The ***Rotating Disk Reactor***: The disks are fixed on a shaft, which rotates on a trough with the waste water. Half of the disks is in the water. While rotating, the biofilm with the micro-organisms on the disks comes into contact with the air. Back in the water, the micro-organisms come into contact with the pollutants to be removed.

The ***Sequencing batch reactor*** is a batch system, where different treatment steps can be performed in one reactor. It requires a more sophisticated electronic control system, but has a very small area requirement.

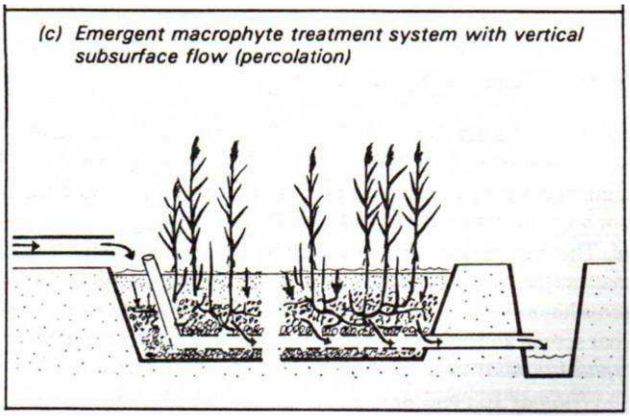
Treatment in a ***membrane reactor*** is usually a combination of one of the above mentioned systems with a membrane which has pores with a definite width and is thus impermeable for bacteria and sometimes even for viruses. In spite of the recent progress of the technology, it still requires sophisticated maintenance (cleaning of the membranes).

Natural treatment plants

In the natural treatment plants the same basic processes take place like in the technical treatment plants. The difference is, that they usually require no artificial oxygen input. They also have a mechanical pre-treatment. As the natural systems work with mainly natural means, they need a larger area to prevent overloading of the system. They have a large retention time and/or filter the water. The biological diversity is much higher, than in conventional systems. They have a good disinfection property.

In ***Ponds*** the Purification is ensured thanks to a long retention time, in several watertight basins, placed in series. The number of basins most commonly used is 3.However, using a configuration with 4 or even 6 basins makes more thorough disinfection possible. The basic mechanism, on which natural lagooning relies upon, is photosynthesis. The upper water layer in the basins is exposed to light. This allows the development of algae which produce the oxygen that is required for the development and maintenance of aerobic bacteria. The area requirement is about 5 to 10 square meters per person. With a permanent open water surface the risk of disease transmission in ponds is higher than in constructed wetlands.

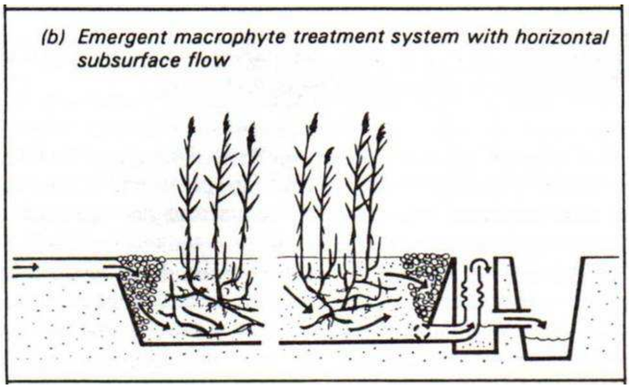
Constructed Wetlands are a technology designed to mimic processes found in natural wetland ecosystems. These systems utilise wetland plants, soils and their associated micro-organisms to remove contaminants from wastewater, as well as other sources. The filters are excavations, sealed with plastic liner or concrete, to be impermeable, and filled with successive layers of gravel or sand. The reuse, or reclamation, of wastewater, using constructed wetland technology, also provides an opportunity to create or restore valuable wetland habitat for wildlife and environmental enhancement. The wetlands can be designed with vertical flow or with horizontal flow. Constructed Wetlands do not need a final clarifier.



Vertical flow system

Vertical Flow: After mechanical pre-treatment, the influent is distributed directly onto the surface of the filter. During flow through the filter media, it is subject to a physical (filtering), chemical (adsorption, complexing, etc.) and biological treatment. The purifying principle lies in the development of an aerobic biomass attached to a reconstituted soil. The treated water is drained. Within the same plant, the filtering surface is separated into several units which makes it possible to establis periods of treatment and inactivity for recovering. Oxygen is supplied by convection and diffusion, due to the surface distribution of the water, and by the roots and rhizomes of the plants. The area requirement under tropical conditions is between 1,5 to 2 square meters per person.

Horizontal Flow: After mechanical pre-treatment, the water passes the filter media horizontally. No water appears on the surface. The mechanisms are similar to the vertical system, but the oxygen supply depends only on the plants. This requires a surface area about 2 to 3 times more, compared to the vertical system.



Horizontal flow system

What is the best *pre-treatment* for the constructed wetland ?

As pre-treatment septic tanks can be used.

Composting unit

The most important part is the outflow. By installing a “T” or a baffle, the outflow of scum layer particles has to be prevented. As alternative for the septic tank a composter can be installed. This device consists of a tank, with a porous lining, acting like a sieve for the waste water. The composted solids are like soil and can be handled and reused easily. Instead the sludge from the septic tanks has to be removed and dewatered prior to use. The advantage is, avoiding odor problems and dewatering of the sludge.

Are constructed wetlands *reliable ?* What do they treat ?

When applied appropriately and constructed properly, treatment wetlands can effectively remove most pollutants associated with municipal and industrial wastewater and stormwater. Treatment wetlands are especially efficient at removing organic contaminants (expressed as BOD - biochemical oxygen demand, or COD – chemical oxygen demand), suspended solids, nitrogen, phosphorus, hydrocarbons and even metals and bacteria. Constructed wetlands are an effective and reliable water reclamation technology, if they are maintained and operated properly. They have the same or better performance, compared to technical systems.

Is the use of constructed wetlands *limited* by location or climate?

This technology can be applied in a wide range of geographic areas including arid, tropical, and alpine regions, and can even treat nutrient rich effluents in extreme weather conditions. Constructed wetlands projects can range widely in size, shape, and location, with a major constraint being the amount of land required.

Belzig, Germany (temperate)

What are the major *maintenance* issues associated with wetland treatment technology?

Every waste water treatment system requires maintenance. In average, the constructed wetlands however, need less maintenance, compared to the technical systems. The main critical points to be monitored thoroughly are the mechanical pre-treatment and the water distribution system, and, to a lesser extend, the weed development.

What are the *materials* to be used for construction ?

The big advantage of the constructed wetlands is, that most of the material can be acquired locally. For sealing, plastic liner or concrete can be used, depending on the price or your preference. The filter media usually is locally available. Before use, it has to be evaluated carefully – this is the most critical point of construction. The plants can be found locally. Usually common reed is best performing, but with vertical systems almost any plant species can be used. Pumps and polyethylene pipes are usually available everywhere.

How much does a constructed wetland *cost* ?

The costs depend mainly on the size of the treatment plant. When you are in a decision process for a waste water treatment plant, you have to consider both the investment and the running costs.

Important part of the investment costs are the sealing of the system and the filter media. Sealing is necessary only, if the mineral soil is permeable. If there is impermeable clay soil, you do not need to seal the treatment plant. Prior to selecting the filter sand, it has to be checked properly. Sometimes the nearest source is not the best one. But usually the right material can be found within a radius, allowing for a cheap transport.

In average, especially, if cheap local labour can be used, the construction costs are much less, compared to technical treatment plants. For example, the construction costs for the first vertical wetland on the Philippines, a treatment plant, which serves 3.500 inhabitants, are …………

The maintenance costs of constructed wetlands are generally much lower than the costs of technical systems.

Which skills are needed for *operation* ?

The operator should have a technical or biological basic education. The specific skills for the operation of the wetland have to be transferred to the operator before start-up of the plant. This can be done by the planning engineer and takes only some hours.

How many constructed *wetlands* are existing *in the area* ?

On the Philippines the following constructed wetlands are in operation:
……
Bayawan, Oriental Negros, municipal waste water, 700 persons (2006) 3,500 persons (2007).

Many constructed wetlands exist in other tropical countries, like Thailand.

What are the main *Pro´s and Con´s* of Constructed Wetlands ?

The benefits of constructed wetlands for wastewater treatment are:

- They are relatively inexpensive to construct and operate
- They are easy to maintain
- They provide effective and reliable wastewater treatment
- They can tolerate both great and small volumes of water and varying contaminant levels
- They can be aesthetically pleasing and provide habitat for wildlife and human enjoyment

The disadvantages of constructed wetlands for wastewater treatment are:

- Depending on the design, they may require a relatively large land area compared to a conventional facility
- The design and operating criteria under tropical conditions are not yet totally precise.

Bayawan, Oriental Negros

Where can I *visit an operating plant* ?

For municipal waste water treatment, the Bayawan treatment plant can be visited (Contact: ….)

A good example for an industrial waste water treatment plant …..

Who can *answer* further *questions* and who is able to *plan* a constructed wetland for me ?

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….
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