Case study of sustainable sanitation projects

Constructed wetland for a peri-urban housing area Bayawan City, Philippines

Fig. 1: Project location

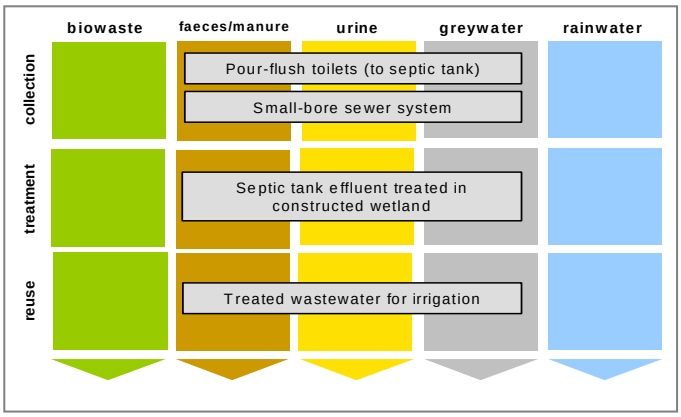

Fig. 2: Applied sanitation components in this project

1 General data

Type of project:

Peri-urban upgrading of a settlement; domestic wastewater treatment with constructed wetland (or reed bed)

Project period:
Start of planning: Feb 2005
Start of construction: June 2005
Start of operation: Sept 2006 (and ongoing)

Project scale:
Relocation housing area for 676 houses (average household size of 5 people, although some houses contain more than one family); design figure: 3380 people.

Total construction cost for the constructed wetland was about EUR 160,000 including consultancy and labour.

Address of project location:

Fishermen's Gawad Kalinga Village, Barangay Villareal, Bayawan City, Philippines

Planning institution:
City of Bayawan, Philippines
Oekotec GmbH, Belzig, Germany
Gerry F. Parco & Marc Mulingbayan, Philippines

Executing institution:
City of Bayawan, City Engineering Office

Supporting agency:
Department of the Interior and Local Government (DILG)-GTZ Water & Sanitation Program (but only for consultancy fees and various technical assistance - not for construction itself which was financed by Bayawan City)

2 Objective and motivation of the project

The objectives of the project were to:

- Protect coastal waters from pollution with domestic wastewater.
- Protect the health of the local residents through improved housing with safe sanitation and wastewater treatment facilities.
- Demonstrate constructed wetland technology. Bayawan was the first city in the Philippines that built a constructed wetland for domestic wastewater treatment. Therefore, one of the objectives was to use it as a pilot and demonstration project for other communities.

3 Location and conditions

Bayawan City is located in the south-west of Negros Island, covering a total land area of about 70,000 hectares and with a population of about 113,000. The project is located in a peri-urban area of Bayawan, which has been used to resettle families that lived along the coast in informal settlements and had no access to safe water supply and sanitation facilities. Records from the City Health Office showed a high incidence of morbidity and mortality arising from water-borne diseases in these informal settlements.

Fig. 3: Relocation housing area, Barangay[1] Villareal, Bayawan City, June 2006 (source: Bayawan City).

The families have been resettled to a 7.4 hectares social housing site which consists of 676 terraced houses, a day-

[1] A barangay is the smallest administrative division in the Philippines.

care centre, a health centre, a multi-purpose hall and a community centre. By December 2008, 555 of the houses were occupied (and by September 2009, all 676 houses were occupied). The majority of the households that moved into the relocation area make their living from fishing. The average household size is 5 people, but it has to be mentioned that some of the houses contain more than one family.

One of the projects recently introduced in the Fishermen's Gawad Kalinga Village to diversify their livelihoods, is vegetable and cut flower production using organic farming methods.

The under-five child mortality rate[2] in the Philippines is currently approx. 28 children per 1000 which is relatively low for a developing country (http://www.childinfo.org/mortality.html).

4 Project history

The concept of ecological sanitation was first introduced to the Visayas and Mindanao Regions of the Philippines during the "1st International Symposium on Low Cost Technology Options for Water Supply and Sanitation" in September 2004 in Bohol (speakers and guests came from Philippines, Indonesia and Germany). The conference was organised by the DILG[3]-GTZ Water & Sanitation Program and the WSP (Water & Sanitation Program) of the World Bank.

Representatives from the City of Bayawan attended the symposium and a group of German and Filipino experts subsequently visited Bayawan City to conduct a rapid assessment of the sanitary situation in specific areas. Two wastewater management and sanitation options were identified: a constructed wetland for domestic wastewater of a peri-urban resettlement area (described in this case study) and a dry sanitation concept (urine diversion dehydration toilets) for the sparsely populated rural areas (as described in a separate SuSanA case study).

The first visit of the German and Filipino consultants was in March 2005. The experts assessed the location and design parameters and discussed different technical options with the engineers and officials of the local government of Bayawan City. The detailed design was prepared by Filipino consultants and the construction process was carried out by the City Engineers Office of Bayawan. The Filipino consultants were also responsible for construction supervision.

In April 2005, the partnership between the City Government of Bayawan and the GTZ was formally sealed with a Memorandum of Agreement providing technical assistance in the construction of the constructed wetland treatment facility.

The users were not consulted in the design of the system, only the city government with its various offices, i.e. health, engineering and environment. But the users were involved in the general decision to treat the wastewater in a decentralised facility and not only in septic tanks.

A German consultant (Dr. Joachim Niklas, Oekotec GmbH) visited Bayawan twice during the construction phase, in November 2005 and June 2006. The first visit included the selection of a filter material for the soil filters. A manual for operation and maintenance was developed together with local consultants and the City Engineering Office. The second visit took place when the distribution pipe system was installed in the vertical soil filter.

The construction was carried out by the City Engineering office from May 2005 to August 2006. The constructed wetland was inaugurated in September 2006 and has been in operation ever since. The GTZ sanitation program in the Philippines came to an end in March 2009, and the constructed wetland now continues to be operated by Bayawan City Council.

The implementation phase included social preparation activities for the future inhabitants of the relocation area. As part of the relocation project the City of Bayawan set up a village association to organise the affairs of the relocation area.

The planning process was a joint undertaking of one German and two Filipino Consultants, supporting knowledge exchange and the introduction of a technology which was relatively unknown in the Philippines: the constructed wetland (also called: vegetated vertical soil filter or reed bed).

5 Technologies applied

The houses in the resettled fishermen's village have pour-flush toilets. The wastewater from the toilets, bathrooms and kitchen sinks is partially treated in septic tanks where solids are settled and the organic load is reduced[4]. There are a total of 67 septic tanks, each receiving the wastewater from 6 to 10 houses. The liquid portion of the wastewater (overflow from septic tanks) is transported through a small-bore sewer system with a 250 mm diameter pipe sloped at 0.2% towards the main sump for storage and additional solids removal.

From the main sump, the wastewater (septic tank effluent) is pumped into four header tanks and then flows by gravity into the first cell of the constructed wetland, which is a vertical soil filter. From here, the wastewater flows by gravity into the second cell. This cell is a horizontal soil filter. The effluent from the second cell is collected in the effluent sump.

The faecal sludge from the septic tanks will be treated in drying beds that are located at the sanitary landfill. Emptying of the septic tanks has not yet been necessary, but is expected to be carried out in 2009. The drying beds will be ready for operation soon after Sept. 2009[5].

[2] The under-five mortality rate is the probability (expressed as a rate per 1,000 live births) of a child born in a specified year dying before reaching the age of five if subject to current age-specific mortality rates.

[3] DILG is Department of the Interior and Local Government.

[4] Bayawan City had started with the construction of the septic tanks before the idea of the wetland was conceived. They are designed as 3-chamber tanks.

5 Jouke Boorsma on 2 Sept. 2009: "*The septic treatment system is almost operational. As of now, we are waiting for the waterproofing to be applied in the storage tanks. At one of the beds we applied concrete tiles. If it will give us a positive result, we will apply it on the other beds as well.*" For photos see link in Section 13.

The treated wastewater is pumped from the effluent sump into an elevated storage tank and is used for irrigation mainly in the cut flower and vegetable farming project of the GK Fishermen's Village.

The combination of septic tanks, small-bore sewers and constructed wetland was built because the construction of the houses in the relocation area was already in progress when the City of Bayawan decided to upgrade the treatment process. The city looked for an affordable and reliable treatment technology that could easily be implemented, operated and maintained. Also the treated wastewater should be clean enough for different reuse options, for example as water for construction or irrigation.

A combination of a vertical and a horizontal vegetated soil filter was recommended to ensure suitable treatment efficiency, and taking into account the available space.

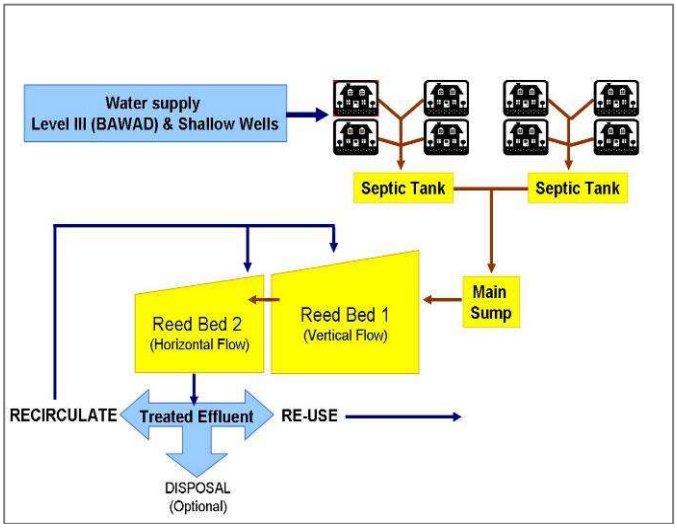

Fig. 4: Flow chart of the treatment system (source: City Engineering Office, Bayawan City).

Fig. 5: Preparation of drainage system of cell 1 of the constructed wetland (vertical flow), January 2006 (source: DILG-GTZ Program).

6 Design information

The constructed wetland was designed for a flowrate of 50 litres per person per day for a total population of 3,000 people (600 one-family houses[6] with on average 5 people per household) and a BOD concentration of 300 mg/l. At the last count, 555 houses were occupied (December 2008)[7]. This would result in a wastewater flowrate of 140 m^3/d and BOD load of 42 kg/d. To this date, the actual flowrate has not been measured.

The actual BOD concentration in the influent was determined to be 138 mg/L in a study in Oct. 2009 by Jonah Butler, a PhD student in 2009 and Fulbright scholar (jonahsbutler@gmail.com).

Based on these design parameters the calculated required area for a design flowrate of 150 m^3 per day (600 families or 3,000 people) are: 1800 m^2 for the vertical soil filter (cell 1) and 880 m^2 for the horizontal soil filter (cell 2). The dimensions of cell 1 are 48 m x 36 m and for cell 2 they are 33 m x 27 m.

The total surface area is 2680 m^2 and the wetland has a specific surface area of 0.9 m^2 per person (a relatively low design figure and hence "optimistic" design – made possible by the low per capita flowrate, the sewage pre-settling in the septic tanks and the tropical temperatures).

The total depth of the filter basins is 2 m (for module 1) and 1.2 m (for module 2) from the concrete bottom to the top of the wall (including the drainage systems and about 0.60 m of free board). The filter layer itself is 0.6 m in both cases. The water flows by gravity through the distribution system and a constant head assures an even distribution of the wastewater over the whole area of the cell.

Both the village and the constructed wetland are close to the sea shore and during the rainy season groundwater rises to ground level. Both cells of the wetland were therefore built of concrete and concrete blocks. A drainage system has been positioned at the bottom of each cell which is covered by a separation layer and then the filter layer.

The plants used in the filter are locally available reed called 'tambok' (*Phragmites karka*). It was grown during the construction phase in a nursery at the relocation site. The tambok was cut for the first time in 2008 and it was decided that it should henceforth be cut annually. The reeds also act as an odour barrier during the filling process of cell 1.

The wastewater distribution system is composed of 4 concrete header tanks and a system of perforated HDPE pipes. The system is operated manually, i.e. switching on and off of the pump and emptying the header tanks into the distribution system. The header tanks are filled 2 to 3 times a day.

Since coming into operation, the system has been continuously improved. The header tanks were covered to minimise odour during the filling process and the collection sumps between the two wetland cells and after the second cell were covered to reduce algae growth. Additionally, a large storage tank for the treated wastewater was built.

The local water service provider regularly analyses the influent and effluent of the constructed wetland. This analysis includes TDS, pH, BOD, ammonia, nitrate and phosphate as

[6] In fact, 676 houses were built.
[7] By Sept. 2009, all 676 houses were occupied.

well as the microbiological parameters *E. coli* (effluent quality data is shown in a recent paper by Sullivan University, see Section 13).

The analysis of the treated wastewater showed very good pollutant removal efficiency (97% removal of BOD). The analysis is usually carried out on a monthly basis, but sometimes the lab runs out of reagents for some of the tests. For information on pathogen concentrations in the treated wastewater, see Section 7 below.

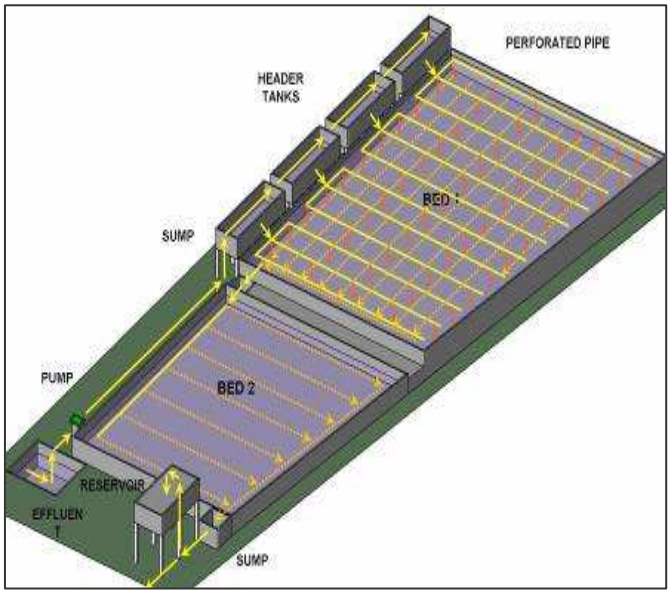

Fig. 6: Flow directions of cells 1 and 2 of the constructed wetland (source: City Engineering Office, Bayawan City).

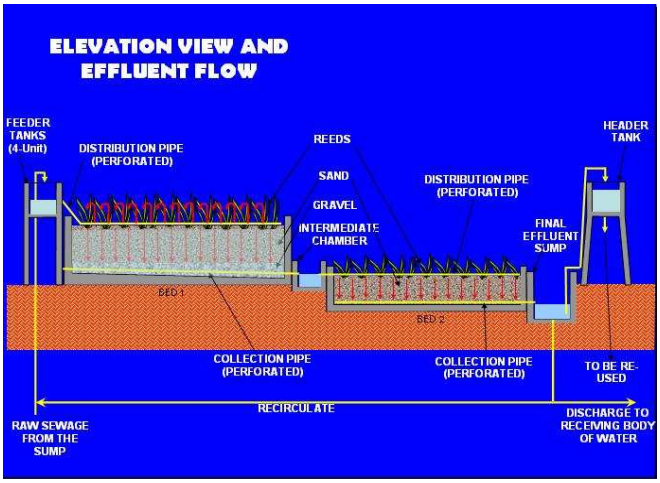

Fig. 7: Diagrammatic components of the engineered wetlands and its effluent flow (source: CENRO, Bayawan City).

Fig. 8: Constructed wetland when construction was just completed in September 2006 (source: GEOPLAN Cebu). On the left side, the header tanks are visible.

7 Type and level of reuse

The treated wastewater was initially used in construction, i.e. for concrete production, and this reduced construction costs. It is also used for the organic cut flower and vegetable farming project of the GK Fishermen's village.

Only a basic microbiological analysis on the effluent from the constructed wetlands was conducted. However since November 2008 a more frequent and exact monitoring has been conducted to analyse for faecal coliforms. The effluent has almost ideal concentrations of nitrate and phosphate to be used for "fertigation" (fertiliser plus irrigation) for the vegetable and cut flower project.

The more advanced analysis of total coliform however showed that the pathogen concentrations remain too high for unrestricted irrigation (but the total coliforms concentration in the treated effluent is still lower than in virtually all the rivers of Negros Oriental (10,000 - < 100,000 CFU/100ml in rivers)).

The farmers were informed of the findings and asked to apply certain safety measures as recommended by the WHO guidelines of 2006 for the safe use of wastewater and excreta[8], i.e. wearing gloves, watering the soil and not the leaves, to stop irrigating with treated wastewater four weeks before harvest etc.

The addition of a tertiary treatment step has also been discussed with the Bayawan City Administration to eliminate the high pathogen concentrations.

[8] Available: http://www.who.int/water_sanitation_health/wastewater/gsuww/en/index.html

Constructed wetland for a peri-urban housing area Bayawan City, Philippines

Fig. 9: Reuse of treated wastewater for irrigation in the GK Fishermen's Village in March 2008. Note: it would be preferable if the resident was wearing gloves (source: DILG-GTZ Program).

Through information campaigns during the implementation phase of the wetland project as well as during the training sessions of the organic farming project, residents have learned of the potential benefits of using treated wastewater. Its use for irrigating the vegetable fields was easily accepted. In 2008 a pipe system with tap stands was installed for the vegetable fields. The wastewater is pumped from the effluent sump into an elevated tank which supplies the irrigation system.

This elevated tank is also used by the fire brigade and as a water source for construction purposes (since the tank is elevated, vehicles can be filled by gravity).

The use of the treated wastewater for this triple purpose substitutes the use of water from public supplies and thus results in an overall saving of money. In the irrigation system the treated wastewater is piped to the garden and distributed via a system of standpipes, thus facilitating work which otherwise would have involved collecting water from a single hand-pump. The nutrients in the treated wastewater also result in a saving on fertiliser.

8 Further project components

Treatment and reuse options for the faecal sludge from the septic tanks are part of the solid waste management program of Bayawan and are still in the planning stage (the new landfill is expected to be operational beginning of 2010).

The constructed wetland project complements other programs being implemented and developed by Bayawan City such as the Healthy City, Food Security, Integrated Solid Waste Management, the 'Character First' and the Organic Farming programs.

9 Costs and economics

The total construction cost for the constructed wetland was about EUR 160,000 including consultancy and labour. Bayawan City financed the bulk of this construction cost with the help of a loan from Worldbank. The DILG-GTZ Water and Sanitation program covered the costs for the international consultant, for workshops, community participation and social preparation sessions – i.e. provided technical assistance and the "soft" component of this project. An exact break-down of the construction cost is not available.

The operation and maintenance costs are estimated at EUR 3,500 per year, including EUR 200 for electricity and EUR 3,300 for labour. This is paid for by the city administration.

The households of the relocation area pay for their private water and electricity consumption but not for the operation of the wastewater treatment facility. Also the gardeners do not have to pay for using the treated wastewater for irrigation. So far the service of providing wastewater treatment is paid out of the city's budget.

10 Operation and maintenance

The staff of City Engineering as well as members of the village association attended training sessions in the operation and maintenance of the wastewater treatment plant. Operation and maintenance are carried out by different teams that are employed by the City and include:

Field Operations

- Pumping and distribution; wastewater feeding schedule; recirculation (the filling and emptying of the header tanks is done manually).
- Management of treated effluent (manual operation of pumps, monitoring of effluent).
- Management of plants / vegetation (cutting of reeds once a year).
- Site security and record keeping of daily activities.

Engineering and Maintenance

- Inspection and repair of electrical lines, pumps, and other equipment.
- Regular inspection and clearing of piping system (monthly, but no cleaning was necessary to date).
- Regular inspection and cleaning of wastewater pretreatment collection system (monthly, but no cleaning was necessary to date).
- Emergency engineering work: Cleaning of soil filter in case of clogging. In June 2008 the walls of cell 1 were reinforced because of fissures between walls and the base. This was caused by hydraulic overload and the cell was at risk of breaking.

Water Quality Monitoring

- Effluent sampling and analysis (see Section 6 for details).
- Keeping a database on water quality analyses and submission of findings and recommendations to the pollution control officer of Bayawan for appropriate action.

Constructed wetland for a peri-urban housing area Bayawan City, Philippines

Fig. 10: Constructed wetland in Bayawan city. The space is between the vertical and the horizontal flow subsurface flow bed (source: J. Boorsma, 2009).

Fig. 11: Constructed wetland and (elevated) effluent tank. The effluent is pumped up into the large storage tank and is used for fire fighting, construction works and irrigation (source: J. Boorsma, Nov 2009).

11 Practical experience and lessons learnt

The constructed wetland is a quite easily built and maintained technical option for wastewater treatment. The vertical soil filter in combination with the horizontal soil filter achieves very good treatment results regarding BOD elimination and nitrification. Regular monitoring of raw and treated wastewater showed that the constructed wetland performs as expected.

Labour is comparably cheap in Bayawan. That made it possible to opt for a manually controlled filling of the distribution system. This option saved construction costs for a larger pump and reduces the operating costs for electricity.

The combination of an international and a local consultant team facilitated an intensive knowledge exchange (mainly between the consultants and the engineers of Bayawan City) and helped to introduce the vegetated vertical soil filter as a new technology option in the Philippines.

The inventiveness of City Engineering staff and the responsiveness of the consultants made it possible to continuously adjust the design to the local conditions (see also last paragraph of Section 6).

Bayawan City plans to build additional constructed wetlands in strategic areas of the city, starting with a wastewater treatment facility for the District Hospital. In Sept. 2009 this wastewater system of the hospital was almost finished (it is an anaerobic baffled reactor and a wetland).

12 Sustainability assessment and long-term impacts

A basic assessment (Table 1) was carried out to indicate in which of the five sustainability criteria for sanitation (according to the SuSanA Vision Document 1) this project has its strengths and which aspects were not emphasised (weaknesses).

Table 1: Qualitative indication of sustainability of system. A cross in the respective column shows assessment of the relative sustainability of project (+ means: strong point of project; o means: average strength for this aspect and – means: no emphasis on this aspect for this project).

	collection and transport			treatment			transport and reuse		
Sustainability criteria:	+	o	-	+	o	-	+	o	-
• health and hygiene	X			X				X	
• environmental and natural resources		X		X			X		
• technology and operation	X			X			X		
• finance and economics		X			X			X	
• socio-cultural and institutional	X			X				X	

Sustainability criteria for sanitation:

Health and hygiene include the risk of exposure to pathogens and hazardous substances and improvement of livelihood achieved by the application of a certain sanitation system.

Environment and natural resources involve the resources needed in the project as well as the degree of recycling and reuse practiced and the effects of these.

Technology and operation relate to the functionality and ease of constructing, operating and monitoring the entire system as well as its robustness and adaptability to existing systems.

Financial and economic issues include the capacity of households and communities to cover the costs for sanitation as well as the benefit, e.g. from fertilizer and the external impact on the economy.

Socio-cultural and institutional aspects refer to the socio-cultural acceptance and appropriateness of the system, perceptions, gender issues and compliance with legal and institutional frameworks.

For details on these criteria, please see the SuSanA Vision document "Towards more sustainable solutions" (www.susana.org).

Constructed wetland for a peri-urban housing area Bayawan City, Philippines

With regards to long-term impacts of the project, the main impacts of the project are:

1. The constructed wetland has reduces water pollution and improved public health (e.g. reduced rate of diarrhoea and intestinal worms in children – although this has not yet been documented).
2. It has served as a demonstration site so that local engineers and decision-makers gain confidence in the use of constructed wetlands.
3. It has resulted in water savings where the treated effluent replaced irrigation water, water for construction purposes and the fire brigade (if there is a fire).

13 Available documents and references

- Guino-o, R. S., Aguilar, A. S., Oracion, E. G. (2010) The efficiency and social acceptability of the constructed wetland of Bayawan City, Negros Oriental, paper under review by the editorial board of Silliman Journal, Silliman University, Philippines http://www2.gtz.de/Dokumente/oe44/ecosan/en-efficiency-acceptability-constructed-wetland-2009.pdf
- GTZ (2008) FAQs Constructed Wetlands. A Sustainable Option for Wastewater Treatment in the Philippines, GTZ-Philippines and Bayawan City. http://www2.gtz.de/Dokumente/oe44/ecosan/en-FAQs-constructed-wetlands-2008.pdf
- Bayawan City (2007) Bayawan City adopts ecosan as a tool for health and environmental management, Mayor Herman P. Sarana, presented at International Conference on Sustainable Sanitation, Dongsheng, China, 28 August 2007, http://www.ecosanres.org/icss/proceedingspresentations.htm (under: 28 August 16:00-17:30, Room #2) or: http://www2.gtz.de/Dokumente/oe44/ecosan/en-bayawan-city-adopts-ecosan-2007.pdf
- Niklas, J. (2006) "Short Term Expert Report III: Implementation of a soil filter treatment plant for water reuse in Bayawan, Oriental Negros", Consultancy Report by Oekotec GmbH, July 2006. http://www2.gtz.de/Dokumente/oe44/ecosan/en-implementation-of-a-soil-filter-treatment-plant-2006.pdf

Video clips on YouTube (the implementation process was documented through a video documentary that covers both the social and the technical aspects of the project):
http://de.youtube.com/watch?v=psf3MrgdXJM
http://de.youtube.com/watch?v=pucWtguIJZ8
http://de.youtube.com/watch?v=jJWXBUNwAwQ
http://de.youtube.com/watch?v=HaXksWDUSDI

Photos of this constructed wetland (from 2009) are available via flickr:
http://www.flickr.com/photos/gtzecosan/sets/72157622251701207/

Further documents can be requested through the DILG-GTZ Water & Sanitation Program, www.watsansolid.com.ph.

14 Institutions, organisations and contact persons

Owner of the system:
LGU Bayawan City, City Hall,
Bayawan City, Oriental Negros,
Philippines
mayor@bayawancity.gov.ph
www.bayawancity.gov.ph

Operator of the system:
City Environmental and Natural Resources Office (ENRO)
Bayawan City, Oriental Negros
Contact person: Mr. Antonio Aguilar
E-mail: tons.aguilar@yahoo.com.ph
And Jouke D. Boorsma (DED Adviser on both liquid and solid waste for the City of Bayawan)
E-mail: joukedouwe.boorsma@ded.de or joukeboorsma@gmail.com

Supporting agency:
DILG-GTZ Water & Sanitation Program,
Contact at GTZ Philippines: Hanns-Bernd Kuchta[9]
5th Fl. DILG-WSSPMO,
Francisco Gold Condominium II,
EDSA corner Mapagmahal Street,
PO Box 1176 QCPO, Diliman,
Quezon City, Metro Manila
Philippines
gtzwater@info.com.ph
www.watsansolid.com.ph

International consultant for constructed wetland:
Oekotec GmbH, Dr. Joachim Niklas
Rosa-Luxemburg-Str. 89
14806 Belzig
Germany
info@oekotec-gmbh.com
www.oekotec-gmbh.com

Case study of SuSanA projects

Constructed wetland for a peri-urban housing area, Bayawan City, Philippines

SuSanA 2010

Authors: Ulrike Lipkow (formerly GTZ Philippines, now: ulrike.lipkow@gmail.com), Elisabeth von Münch

Editing and reviewing: Carola Israel (GTZ ecosan programme - ecosan@gtz.de)

This document is available from:

www.susana.org

[9] Hanns-Bernd Kuchta is program leader until the program ends in June 2010. The sanitation component of the GTZ program was completed in March 2009.