sustainable sanitation alliance

Case study of sustainable sanitation projects

Wastewater treatment using constructed wetlands Tirana, Albania

Fig. 1: Project location

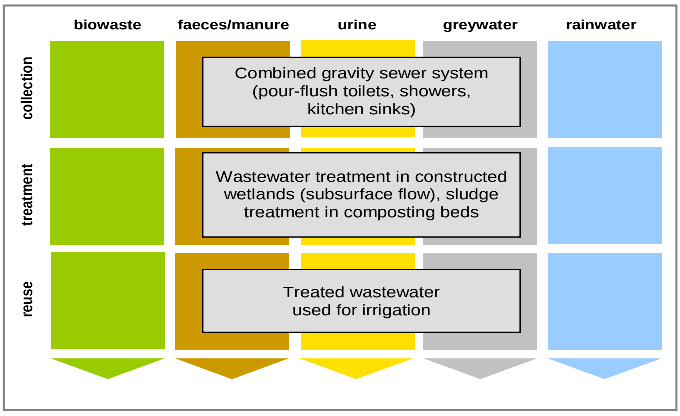

Fig. 2: Applied sanitation components in this project

1 General data:

Type of project:
Full scale, urban research and demonstration project

Project period:
Start of planning: September 2008
Start of construction: September 2009
End of construction: December 2009
Start of operation: January 2010
Monitoring ongoing

Project scale:
Design value: 16.8 m^3/d domestic wastewater for 500 people or 220 population equivalent (P.E., design value and actual utilisation is identical)
Capital cost: EUR 60,000

Address of project location:
SOS Children's Village Albania, Rr. "Hermann Gmeiner", Sauk, Tirana, Albania

Planning institutions:
ÖKOTEC GmbH, Belzig, Germany
Environmental Engineering Department at the Faculty of Civil Engineering at Polytechnic University of Tirana, Tirana, Albania

Executing institution:
Gener2 Construction Company, Tirana, Albania

Supporting agency:
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH/ German International Cooperation, Eschborn, Germany
General Directorate of Water Supply and Sewerage (GDWSS), Tirana, Albania

Financed by:
German Federal Ministry for Economic Cooperation and Development (BMZ) via GIZ Albania: 80%
Albanian Ministry of Public Works and Transport (MPWT): 20%

2 Objective and motivation of the project

As part of Albania's intended accession with the European Union (EU) environmental standards in the water supply and sewerage sector are gaining in importance, particularly the EU Water Framework Directive. This calls for considerable legal and sector policy reforms accompanied with appropriate technologies.

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

Fig. 3: Elementary School of the SOS Children's Village in Sauk, a suburb of Tirana (GTZ Tirana, Sept. 2010)

Being the first system of its kind in Albania, the construction provides for an applied science perspective on this "low rate" wastewater treatment process which uses a combination of both vertical and horizontal subsurface flow constructed wetlands (also called reed bed filters). The application of this technology demonstrates a sanitation system which protects natural resources and promotes sustainability.

3 Location and conditions

Despite promising reform processes in the water and sewage sector, the country is still confronted with major challenges in providing sufficient access to drinking water and sanitation, particularly in providing wastewater treatment. In its National Strategy for Development and Integration, the Albanian government aims to reach 98% water access in 2015 from 73% in 2007. In the same period, the connection rate to sewage systems is to improve from 43% to 80% and wastewater treatment from almost 0% to 50%.

In Tirana, the capital of Albania, untreated sewage is discharged into the Lana River. So far, the public sewer system does not cover the suburban areas. For peri-urban and rural areas the most common means of sewage disposal are seepage pits. In these facilities the solids are kept back, while the wastewater infiltrates into the ground where groundwater is contaminated by the nutrients and pathogens of the wastewater. The SOS Children's Village is located in Sauk, a suburb of Tirana, without connection to the municipality's sewerage system, therefore a decentralised solution was required.

Fig. 4: Arial view of the SOS Children's Village in Sauk (Google, Oct. 2008)

The SOS Children's Village is a worldwide operating orphan and abandoned children's charity which provides shelter and education to children living within and in the surrounding of the community. This international NGO is financed by donations. The SOS Village in Tirana has thirteen "houses" for orphans and other children who do not have proper family structures. Each house has 5 to 7 children in residence, plus one adult taking care of them. The village also serves children that come on a daily basis for schooling and other activities within the children's nursery and elementary school. In total there are around 500 people living, visiting or working at the Village.

Typically for the Mediterranean climate, Tirana has hot, dry summers up to 40°C and cold, wet winters down to -8°C. The average annual temperature is 16°C and with an annual rainfall of 1,200 mm. The city lies on a plain with an average altitude of 110 meters beside the Mount Dajti. The distance to the Adriatic Sea is about 30 km. In Albania, the under-five child mortality rate[1] as surveyed in 2010 is 18 children per 1000, which is very low.

Prior to the project, the SOS Children's Village had a sewage system collecting wastewater in a septic tank with three chambers and then discharging the effluent into a natural stream next to its property. This caused pollution of the stream as well as a health risk for all getting in touch with this stream (such as children playing nearby).

4 Project history

To upgrade the existing treatment unit, GIZ, the SOS Children's Village and the Tirana Municipality's Unit 2 (unit stands urban district) agreed to build a constructed wetland system on the village's premises under technical guidance of Oekotec GmbH and in collaboration with the Polytechnic University of Tirana. The aim was to improve the environmental situation of the village and to raise awareness for decentralised sanitation technologies to relevant stakeholders and the public in Albania.

The planning phase started in September 2008, followed by the implementation phase which began in September 2009 and ended in December 2009. The treatment plant started operation in January 2010.

The construction and start-up was scientifically monitored by the Polytechnic University of Tirana (Environmental Engineering Department).

5 Technologies applied

The constructed wetland system uses the existing sewer network and contains the following components: a) a settling tank for separation of the suspended solids, b) a pump chamber for application of the wastewater to the filter beds, c) a sludge drying bed, d) three filter beds (subsurface flow) for treatment and e) a storage tank for the treated wastewater for reuse on irrigation plots with overflow into the stormwater drain.

Wastewater generated by toilets, showers and kitchen sinks of the houses, school, kindergarten, administration office and canteen, is first pre-treated in the former 3-chamber septic tank which is now rebuilt to a *Dortmund* settling tank, which reduces both BOD and TSS, a second settling tank and a pump chamber. The sludge collected in the settling tank is pumped to a sludge drying bed.

The total area of the treatment system (including pre-treatment, paths etc.) is around 1,600 m²:

- 550 m² taken by the reed beds (165 m² by the two vertical beds and 220 m² by the horizontal bed)
- 72 m² amount for the sludge drying bed
- Space for pre-treatment, collection tanks, pumping station and space/paths between the parts of the plant.

The complete area is surrounded by a fence.

[1] 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 (http://www.childinfo.org/mortality.html and http://www.childmortality.org/).

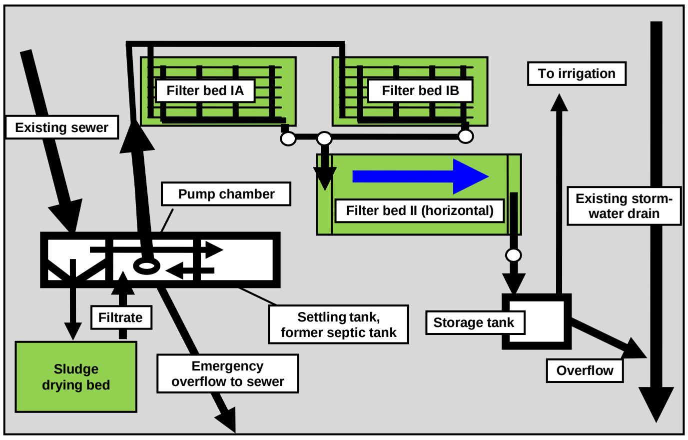

Fig. 5: Flow diagram of the wastewater treatment plant (WWTP) (filter beds IA and IB are vertical flow, filter bed II horizontal flow (subsurface)) (source: adapted from J. Niklas, 2009).

From the first settling tank the liquid effluent flows into the second settling tank and then to the pump chamber, from where it is pumped to a series of two vertical and one horizontal constructed wetland (filter bed I and filter bed II). The surface of the filter beds is planted with a local variety of reeds: *phragmites communis* (see also Fig. 8).

By passing the filter layers, the wastewater is treated by biological and physical (filtering) processes.
The flow from the pump chamber is distributed across the filter bed influent surface area by means of perforated distribution pipes installed on top of filter beds Ia and Ib, alternating daily, and from there by gravity flow into filter bed II. Filter bed I is a vertical bed with subsurface flow, wherein the influent is distributed across the inflow surface area and the wastewater is allowed to infiltrate vertically down to a collection layer at the bottom of the bed. From there it flows by gravity to filter bed II where it enters through a gravel layer, and percolates horizontally through the root-sand media of this horizontal flow bed. The serial connection of constructed wetlands is very helpful to guarantee good effluent values. Especially the combination of a horizontal flow bed after a vertical flow bed has proved to be very successful.

The treated wastewater is collected at the end of filter bed II by a gravel layer with discharge into a small control shaft at one corner of the wetland cell. From this sump, the wastewater is transferred by gravity into a storage tank and either reused for irrigation of the garden or toilet flushing in the school. Treatment achievements are within international standards (WHO guidelines, Volume 4, 2006) for wastewater quality (see Table 1).

Table 1: Measurements of influent and effluent quality (Number of samples unknown.)

Concentration	Influent (mg/l)	Effluent (mg/l)
TSS	400	2
BOD	300	5
COD	600	30
NH_3-N	60	3
NO_3-N	0	57
P (total)	10	6

The wastewater of about 500 people equal to 220 population equivalent (P.E.) is treated (see Table 2). The total wastewater generation is calculated with a flow rate of 16.8 m³/d corresponding to a generation rate of 76 l/person/day.

Table 2: Basic design assumptions for the constructed wetland system at SOS Children's Village Tirana to calculate the population equivalents (P.E.)

No of persons	Category	Duration of presence (h)	Factor	Population equivalents (P.E.)
70	Children	24	1	70
21	„Mothers and aunts“	24	1	21
2	Family of the technician	24	1	2
110	External children in nursery	8-15 (17)	0.33	36.3
10	Tutors in nursery	8-15 (17)	0.33	3.3
2	Cleaning ladies	8-15 (17)	0.33	0.66
223	External pupils	8-15 (17)	0.33	73.59
23	Teachers	8-15 (17)	0.33	7.59
10	Canteen staff	8-15 (17)	0.33	3.3
471	**Total**			**218**

6 Design information

Primary treatment system
As a primary treatment step for solids removal, a settling tank is used. This device was reconstructed from the former 3.36 m^3 septic tank. The main installation was an inverse cone that helps to concentrate the sinking solids at a point of the bottom of the tank, where they can easily be removed through a valve and connected pipe onto the sludge drying bed. The wastewater influent takes place in the centre of the tank, 10 cm below the water surface, within a metal cylinder, which forces the water flow down. This enhances the desired settling of the solids. A baffle at the effluent point prevents scum from overflowing the tank. This type of settling tank is called “Dortmund settling tank” in Germany.

The discharge for de-sludging is installed only 20 cm (instead of more than 1 m) below the water surface. Through opening a valve, the sludge is forced out by the water pressure and flows into the sludge drying bed, therefore, there is no need for a pump.

The settling tank is very shallow and only leads to a moderate degree of sludge separation. The third chamber of the former septic tank has been rebuilt to an additional settling tank and connected to the *Dortmund* tank in September 2010 to improve the degree of sludge separation. The overflow of the Dortmund tank goes to the third chamber and then into the former second chamber of the septic tank, where a pump is installed to feed filter beds I and II. The pump can pump 60 m³/h. This value is derived from the porosity of the filter layer. The resulting diameters of the main pipe are 100 mm and the distribution pipes 65 mm, respectively. In the main pipe, near the pump chamber, there are two valves, which are used to feed filter bed IA or, alternatively, filter bed IB.

The pump is controlled by a level switch. The volume of water pumped each time is 5 m³. During dry periods feeding takes place 3 to 4 times a day. During rainy periods additional rainwater enters the system, the feedings takes place more often (detailed numbers do not exist). The volume of the settling tank, limited by the available emergency overflow into the existing sewer, is 35 m³. Due to occasional electricity breakdowns, the storage capacity lasts for two days.

Filter bed IA and IB (vertical flow)

Filter bed I is divided into two separate compartments, which can be operated independently. Each bed has a surface area of 165 m². The media in which the reeds are planted is primarily sand (sand comes from Tirana; size 0-2 mm, $5 \cdot 10^{-4} < k_f < 5 \cdot 10^{-3}$, it has to be noted that finer sand was recommended but not available), with a network of perforated collection pipes in the bottom covered by gravel. The depth of the bed is 0.6 m. Additionally, there is the provision of 0.3 m of freeboard. The bed is sealed at the bottom using a geo-membrane (polyethylene liner) towards the soil. The gravel layers in the bed are protected by geo-textile. A geo-textile is not usually recommended, see Hoffmann et al. (2011). The beds are fed alternately: One is fed for one week and then remains out of service for one week and recovers during this time. (One bed is fed for one week and then remains out of service for another week to recover while the other bed is used.)

Fig. 6: Lining and drainage piping of Filter Bed IA during construction, before filling with gravel and sand (source: E. Gjinali, Sept. 2009).

The distribution of the wastewater takes place by distribution pipes that are perforated with 8 mm holes in spaces of less than 1 meter on two sides. The 65 mm pipes are fixed on stone slabs and laid parallel lengthwise at 2 m distance. The collection system at the bottom of the bed is composed of perforated PVC pipes covered with gravel. The complete discharge is lead 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.

Fig. 7: Filter bed IB at inauguration with the minister of MPWT/ GDWSS. Reeds have not yet grown (source: A. Kanzler, Jan. 2010).

Table 3: Design data of the constructed wetland system of the SOS Children's Village Tirana

Type	Value	Unit
Total population at full occupancy	220	P.E.
Total WW* flow rate	16.8	m^3/d
Per capita WW generation rate	76.4	L/cap/day
Design hydraulic loading	80	L/P.E.
BOD concentration (estimated)	300	mg/L
Total BOD load	5.0	kg/d
Area of filter bed I	330	m^2
Area of filter bed II	220	m^2
Total area	550	m²
Area per population equivalent	2.5	m^2/P.E.
Hydraulic load, bed I	50.9	L/m^2
Hydraulic load, bed II	76.4	L/m^2
BOD load, bed I	15.3	g/m^2/d

* WW: abbreviation stands here for wastewater.

Filter bed II (horizontal flow)

Filter bed II has a surface area of 220 m² and is sealed with geo-membrane and geo-textile protection like filter bed I. The wetland media in which the reeds are planted is primarily sand (due to a lack of sand available, the same sand is used as in the vertical filter beds IA and IB, what is not an optimal solution). The surface level of the reed bed is slightly lower than the outlet pipe of filter bed I, therefore the effluent from the filter bed I can flow to filter bed II by gravity which results in a continuous feeding of this filter bed. Along one side of the filter bed II is a 60 cm wide strip of gravel, which comprises the inlet area.

On the other side of the bed is a similar strip of gravel which serves as the outlet area. The wastewater flows horizontally from inflow area to outflow area. The filter bed has a slight slope of 1% at the base, while it is exactly horizontal at the surface. Therefore the depth of the bed ranges from 0.6 m to 0.83 m. It has no freeboard which might lead to an overflow of wastewater into the terrain after heavy rains.

Sludge Drying Bed

The sludge drying bed has a surface area of 72 m^2 and is similar to Filter Bed 1, but with thinner layers, which are only 15 cm thick, and planted with the same plants. The inflow of the sludge happens by an open flexible pipe, which can be moved manually for even distribution of sludge. The filtrate passes the sand layer and is collected by drainage pipes, similar to Filter Bed I. It is channelled to the pump chamber and treated in Filter Bed I together with the rest of the wastewater.

Dewatered and stabilised sludge needs to be removed when the sludge layer reaches a height of 30 cm after approx. 3-4 years. The amount of sludge produced is expected to be around 12 g TS/capita*year (TS stands for total solids).

7 Type and level of reuse

In the future (not before 2012) the SOS Children's Village will start making use of the treated effluent for nitrogen-enriched irrigation of the garden (high nitrate levels, see Table 1).

Another important point of reuse, planned in the future, is supplying the flush water for the toilets in the school and kindergarten by treated wastewater. The dried sludge from the sludge drying beds is planned to be used on the garden compound as natural compost after mineralization has taken place (starting from around 2014).

Fig. 8: View on the grown plants in the horizontal bed (source: M. Winker, Oct. 2011).

8 Further project components

By locating the constructed wetland in a SOS Children's Village the project can combine access to sustainable sanitation with practical education of children. The pilot plant can serve as an applied and illustrative aid in the curricula of schools to better understand natural and biological processes and sensitise the young generation for the protection of the environment. Especially the reuse of the treated wastewater in gardening shall motivate the students' participation. In addition, different actors (sector policymakers, waterworks directors, supervisory board members of water utilities) can use the site as a training, demonstration and promotion platform for mainstreaming decentralised wastewater treatment adapted to small and medium sized communities.

There are complementary project measures at meso and macro level to develop capacities of key stakeholders and provide advice to the sector reform process. As such the pilot constructed wetland is embedded in a multi-level approach with potential to mainstream sustainable sanitation approaches and technologies to a wider public.

GIZ, the MPWT and the Polytechnic University of Tirana plan to integrate decentralised, low cost wastewater treatment technologies into training programmes, student internships and workshops in order to promote replication in other peri-urban and rural areas of Albania.

9 Costs and economics

The construction cost for the treatment plant was around EUR 60,000. This consisted of EUR 50,000 for material and construction service, EUR 5,000 for supervision and training as well as EUR 3,000 for documentation and public relations. The remainder was consumed for permissions and other administrative costs. 70% of EUR 50,000 were spent for material and 30% for the construction works.

The constructed wetland system treats the wastewater of 220 population equivalents with a low operating cost of about EUR 500 per year which is covered by the SOS Children's Village. The management requires one pump and only one person on a part time basis for supervision and operation.

Due to the onsite treatment of the wastewater, the village does not have to pay the sewerage fee per liter of wastewater. The fee amounts approx. 10-15 LEK/L.

10 Operation and maintenance

The SOS Children's Village technician, who was trained in operation and maintenance by Dr. Joachim Niklas and Dr. Jens Nowak, is assigned to undertake routine operations of the system. These include:

- weekly inspections and regulating the outflow of sludge of the settling tank
- pumping the wastewater daily into filter bed 1A and 1B alternatively (Details on pumping are not available)
- removal of weeds
- emptying of the grease trap
- removing plant roots in some of the shafts
- harvesting of reeds as well as reuse of treated wastewater for gardening is supported by school children.

For operation and maintenance, 2 hours per week are considered as sufficient. Harvest of reeds is not absolutely necessary till now. The only disadvantage of not doing it is the discharge pipes will not be visible after some time. Care has to be taken that roots do not block distribution system.

Furthermore information, education and communication campaigns are undertaken to ensure that the people in the SOS children's village are using the sanitation system properly so that the constructed wetland is not negatively affected (most importantly not dumping chemicals and oils into the drains).

Maintenance activities concerning the sludge reuse will not take place until about 2014 when the sludge drying beds will be full.

11 Practical experience and lessons learnt

The operation of the treatment plant started in January 2010. The inauguration ceremony was attended by the minister of MPWT of Albania and broadcast in the national media which indicates the significant interest in the first constructed wetland in Albania. This will help to promote the approach and technology.

There have been some operational problems with blockages in the distribution pipes since the start in January 2010 due (to) the poor performance of the pre-treatment. In September 2011 these problems have been identified and solved. Some pipes and valves in the Dortmund tank had not been built as planned and the third chamber of the former septic tank has now been rebuilt to an additional settling tank. A Dortmund tank was chosen as pre-treatment due to the already existing septic tank system but normally another pre-treatment system would have been more appropriate as the Dortmund tank is not able to handle solids and screenings well.

In the vertical filter, the outlet holes in the distribution pipes were placed in such way that the wastewater was leaving the distribution pipes in 2 m high fountains. This caused a kind of spray or mist and a bad smell. The pipes were cleaned and turned that the holes are now going to the side. Additional holes on the opposite side were drilled as well.

The effluent pipe between the shaft of the horizontal filter and the storage tank was placed too high. This caused hydraulic overloading during heavy rain falls (in winter). It was replaced by a lower pipe. The same was done with the overflow outlet (in the storage tank) to the rainwater sewer.

Moreover, at several points in the system, infiltration water entered the system due to various design and construction faults in the piping. These minor problems were corrected.

12 Sustainability assessment and long-term impacts

A basic assessment (see Table 4) 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 4: 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).

Sustainability criteria	Collection transport			Treatment			Transport Reuse		
	+	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, such as from fertiliser 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).

With regards to long-term impacts of the project, the main expected impact of the project is to contribute to improved environmental sanitation in rural and peri-urban areas by introducing adapted decentralised water treatment technologies which are within the EU Water Framework Directive (if more such constructed wetlands are built). This particular pilot project demonstrates the appropriateness and potential of the technology in the Albanian context.

13 Available documents and references

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- FlickR set showing more pictures of this case study: http://www.flickr.com/photos/gtzecosan/sets/72157623262182867/

14 Institutions, organisations and contact persons

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Case study of SuSanA projects:
Wastewater treatment using constructed wetland system, Tirana, Albania
SuSanA 2011

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