FIRST RESEARCH AND DEMONSTRATION WASTEWATER TREATMENT SYSTEM IN ALBANIA USING CONSTRUCTED WETLAND AND REUSE TECHNOLOGIES

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Abstract: This paper provides for a scientific explanation of the application of an extensive wastewater treatment methodology, commonly referred to as a "constructed wetland", which uses a combination of both vertical and horizontal flow through the treatment media. The application of this technology results in a treated water quality, before discharge to the receiving stream, which is in compliance with European wastewater treatment standards, while achieving a low, overall unit cost. It is well understood in international practice that constructed wetland technologies are highly dependent on geological and climate conditions in the region of application, but this should not serve as a barrier for their consideration. The design presented in this paper is based on international standards, and is not only aimed to solve a specific problem, but to also promote a very practical technology for its greater use. Further development and application will require official, national standards, as well as manuals and guidelines that would address the related technical and legal aspects.

1 Introduction

A research and demonstration scale wastewater treatment system has been designed, and is proposed to be constructed, in the Republic of Albania under the funding assistance of the German Technical Assistance Program of GTZ (*Gesellschaft für Technische Zusammenarbeit*). The system is sited to serve a defined land use known as the SOS Children's Village that has no access to formal wastewater collection and treatment, with none planned for the foreseeable future. The proposed treatment technology is a constructed wetland, utilizing a combination of both vertical and horizontal flow. This system has been designed by the German Senior Engineer, Joharim Niklas, in close collaboration with the Albanian Senior Engineer, Enkelejda Gjinali.

2 Site location

The SOS Children's Village is one of 155 similar villages worldwide. It is located in the suburbs of the City of Tirana, the capital of Albania. At this time, the Greater Tirana Metropolitan Area has no wastewater treatment plants, and the wastewater generated and collected within the urban core of the City is discharged, raw, to a channelled waterway, the Lana River, that is the main feature of a greenbelt that runs through the City. The SOS village has its own sewage collection system, which discharges raw sewage into a natural stream next to its property. The investment in a major wastewater collection and secondary treatment system is planned for the Metropolitan Area of Tirana, but it currently does not include the SOS Children's Village within its collection area. The SOS Children's village has thirteen "houses" for orphans and other children who are without proper family structures. Each house has 5 to 7 children in residence, plus one adult considered the "mother" and occasionally "aunts" as substitutes. The Village also serves children that come to the site on a daily basis for schooling and other activities. A children's nursery and an elementary school, with attached eating facilities, make up the major structures of the site. As a reference for the total number of served people refer to Table 1.
The garden inside the SOS property is only partially used, mostly for ornamental plantations between the houses. The village technicians have no idea for any extension of the green area. One idea was

generated due to the discussions with the representatives of SOS in order to implement a vegetables garden as a place for “learning in practice”.

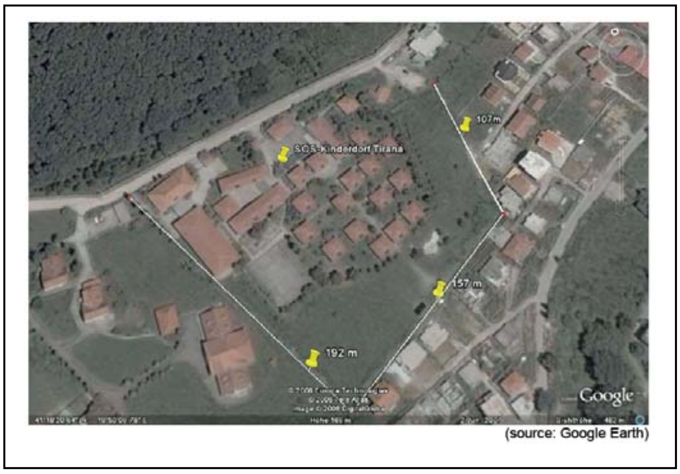

Fig. 1: SOS Children’s village (arrow shows the septic tank location)

Fig. 2: Favoured construction site

3 Loading and expected treatment performance

Based on the size of the population that would need to be served by the planned facility, Table 1 has been developed to calculate a population equivalent load (PE) for the purpose of design.

Tab. 1: Load Calculation for SOS Children’s Village, Tirana

Number	Category	Duration of Presence	Factor	Population Equivalents
70	Children in Village	24 h	1	70.00
21	“Mothers” and “Aunts“	24 h	1	21.00
2	Family of the Technician	24 h	1	2.00
110	External Children in Nursery	8-15 (17) h	0.30	36.30
10	Tutors in Nursery	8-15 (17) h	0.33	3.30
2	Cleaning Personnel	8-15 (17) h	0.33	0.66
223	External Pupils	8-15 h	0.33	73.59
23	Teachers	8-15 h	0.33	7.59
10	Canteen Staff	8-15 h	0.33	3.30
471	**Total Served Population**			**217.74**

The influent concentrations of different contaminants have not been determined yet. Therefore, the performance of the wastewater treatment system, which is presented in Table 2, is an estimate based on experience for comparable situations. The table gives mean values, which can vary. Concerning Nitrate and Phosphorous, there is only a low reduction. This is to allow for reuse of the nutrients as fertilizers. If the water is not used for irrigation, and the reduction of these contaminants is considered a treatment goal, there are cost-effective options, to reduce nitrate to less than 15 mg/L and phosphorous to about 2 mg/L.

Tab. 2: Expected performance of the tretment system

Parameter	Unit	Influent	Effluent from Settling Tank	Effluent from Bed I	Effluent from Bed II
Total Suspended Solids	mg/L	400	100	5	2
Biochemical Oxygen Demand	mg /L O_2	300	300	10	5
Chemical Oxygen Demand	mg /L O_2	600	600	40	30
Ammonia	mg /L NH_3-N	60	60	5	3
Nitrate	mg /L NO_3-N	0	0	55	57
Ortho-Phosphate	mg /L PO_4-P	10	10	8	6
E. coli	CFU/100 mL	10^7	10^7	10^3	10^2

The expectations for this designed constructed wetland system is to produce an effluent with less than 30 mg/liter biochemical oxygen demand (BOD), less than 25 mg/liter total suspended solids (TSS), and less than 10,000 CFU/100mL fecal coliforms.

4 General consideration during the design phase

The following ecological aspects are taken into consideration:
- recycling of sewage sludge;
- optimization of the current wastewater treatment conditions; and
- wastewater reuse after treatment for irrigation and flushing of toilets.

Due to the current conditions of the piping system, there are limited options for an upgrade. The proposed system consists of the following components:
- Dortmund tank for separation of the suspended solids;
- pump chamber for application of the waste water to the soil filters;
- sludge composting bed for recycling of the solids;
- two-stage soil filter beds for optimised hygienic treatment; and
- tank for the treated wastewater for reuse, with overflow, when needed into the storm water drain.

5 Existing wastewater system

Currently, wastewater from the houses, administration buildings and the school flows directly into a septic tank consisting of two chambers and a total volume of approximately 64 cubic meters. The wastewater from the canteen passes through a grease trap prior to entering the sewer system. The sludge extraction from the existing septic tank is removed in more or less regular intervals by a private company and disposed of "somewhere in the countryside". The scum from the grease trap is removed by one of the technicians and disposed of on the premises.

In both cases, a contamination of soils and groundwater cannot be excluded. An upgrade of the wastewater system has, therefore, to consider sludge disposal as well. From the septic tank, the water flows into a pipe, passing through different adjacent properties, which leads to a nearby river. The current receiving stream is overloaded from some additional contributors on the properties crossed by the pipeline, via connected latrines, as well.

One important aspect in the planning of the upgrade to the system is the sewer system itself, which appears to have been laid unnecessarily deep, thus requiring a positioning of the septic tank at the end of the slope near the edge of the property. This was a limiting factor in the number of feasible technical options for upgrade.

6 Description of the proposed constructed wetland wastewater treatment system

As it is shown in Figure 3, the wastewater generated by the flushing from toilets, showers and kitchen sinks of the houses, school, kindergarten, administration office and canteen, at the beginning are mechanically treated in the "Dortmund" settling tank, which reduces both BOD and TSS.

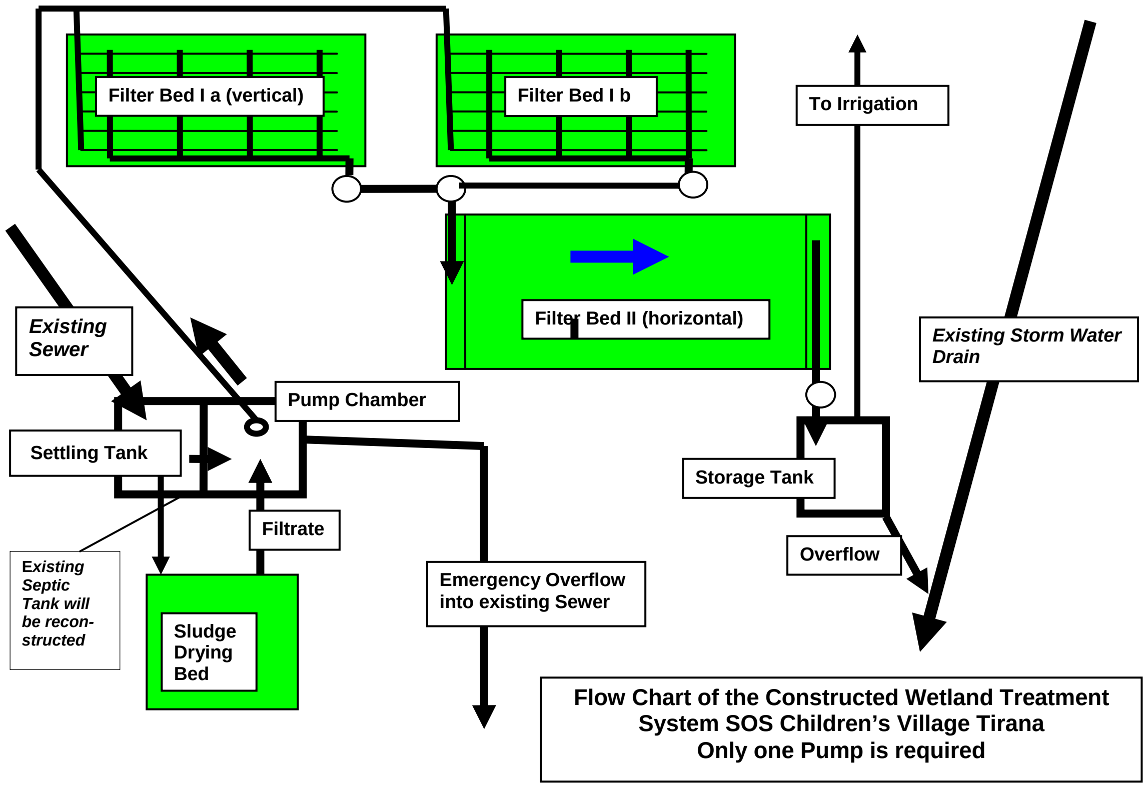

Fig. 3: Process flow chart of the SOS wastewater treatment system

The sludge collected in the Dortmund settling tank flows to a sludge drying bed. The liquid effluent from the Dortmund settling tank flows into a pump chamber, from which it is pumped to a series of two constructed wetland systems (Filter Bed I and Filter Bed II). The surface of the filter beds will be planted with a local variety of reeds. The filter bed surface area has been sized on the basis of 2.5 square meters of bed surface per PE.

The flow from the pump chamber is distributed across the filter bed influent surface by means of perforated distribution pipes installed in Filter Beds Ia and Ib, alternating daily, and from there by gravity flow into Filter Bed II. Filter Bed I is a vertical flow wetland system, 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 the wetland.

It is collected at the end of the bed again 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 collection tank and either reused for irrigation of the garden or toilet flushing in the school.

7 Wastewater System Components

7.1 Primary Treatment System

For mechanical pre-treatment the Dortmund tank is used. Its design parameters are described in Table 3. For this device the former septic tank is reconstructed. Main installation is an inverse cone, that helps to concentrate the sinking solids at a point of the bottom of the tank, where they can easily be pressed out via a pipe. The wastewater influent arrives at 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

Tab. 3: Dimensioning of the Dortmund tank

Specific volume of the tank	30	L/Population Equivalent
Hydraulic load	16.8	m^3/d
Theoretical daily water consumption	150	L/Population Equivalent
Resulting number of population equivalents	112	
Required volume of the tank	3.36	m^3
Minimum inner diameter	2.8	m
Selected floor diameter	0.4	m
Minimum usable height	1.9	m
Minimum total height	2.7	m

The inflow has to be reconstructed, to a higher level, to allow for a better steepness of the cone. This prevents sludge from settling on the slope of the cone. A higher influent is possible by installation of a new pipe from the last manhole, before the existing septic tank. The discharge pipe for de-sludging the tank is installed 20 cm below the water surface. This installation requires no pump, since by simply opening a valve the sludge is forced out by the water pressure and flows into the sludge drying bed.
The overflow from the Dortmund tank goes into the former second chamber of the septic tank, where a pump will be installed to feed Filter Beds I and II. The pump is sized to perform at 60 cubic meters per hour. This value is derived from the porosity of the filter layer. The resulting diameters are 100 mm for the main pipe and 65 mm for the distribution pipes 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 m^3. The volume of the tank, based on the available emergency overflow into the existing sewer, is 35 m^3. Concerning the frequent electricity breakdowns, the safety volume lasts for 2 days. This is much longer than the longest stated power outage.

7.2 Filter Bed I

Filter Bed I is divided into two separate compartments, which can be operated independently. Each bed has a surface area of 165 m^2. 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 is 0.60 meters. Additionally, there is the provision of 0.3 m of freeboard. The bed is sealed at the bottom using a geo-membrane (polyethylene liner), against the soil and the gravel layers in the bed are protected by geo-textile.
The distribution of the wastewater takes place by distribution pipes, that are perforated with 10 mm holes in interspaces of 2 meters. The pipes are fixed on stone slabs and laid in parallels on 2 meter centers. 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.

7.3 Filter Bed II

Filter Bed II has a surface area of 220 square meters 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. The

elevation of the surface of the reed bed media is slightly lower than the outlet pipe of Filter Bed I, therefore the effluent from the Filter Bed I can be fed to Filter Bed II by gravity.
Along one side of the Filter Bed I is a 60 cm wide strip of gravel, which comprises the inlet works. On the other side of the bed there is a similar strip of rocks which serves as the outlet area. The wastewater flows horizontally from the inflow area to the outflow area. The filter bed has a slight slope of 1% at the sole, while it is exactly horizontal at the surface. Therefore the depth of the bed ranges from 0.60 m to 0.83 m. The freeboard is 30 cm.

Tab. 3: Dimensioning of the soil filter beds area

	Area (m²)	Width (m)	Length (m)
Filter Bed Ia	165	8	18.75
Filter Bed Ib	165	8	18.75
Filter Bed II	220	9	24.50
Total	**530**		

7.4 Sludge Drying Bed

The composition of the sludge drying bed is similar to Filter Bed I, but with thinner layers, which are only 15 cm thick. The inflow of the sludge is by an open flexible pipe, which can be directed manually. The filtrate passes the sand layer and is collected by drainage pipes, similar to Filter Bed I.

Conclusions

Currently in the world, a total of 1,640 small-scale, constructed wetlands, as wastewater treatment systems, have been identified. These systems vary widely based on different design parameters, loading rates, and geographical locations. The expanding use of this type of decentralized wastewater treatment technology has resulted in an increased interest in small scale, wetland wastewater treatment system.

The studies conducted and the designs considered to develop this paper were focused on the total lack of information as to how this technology might be applicable to conditions in the Western Balkans, and more particularly in Albania.

The studies addressed, for the first time in Albania, basic data and design criteria needing to be considered to assess the consideration of this technology, such as hydraulics, cold-climate performance, operation and maintenance, vegetation establishment and construction cost.
It can be concluded, based on the studies and designs that Albania, and therefore many other parts of the Western Balkans, are well suited to the application of small scale, constructed wetland wastewater treatment systems, and that their use should be encouraged as one added treatment strategy to meet the future standards of the Water Directives of the EU.

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