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POTENTIAL OF CONSTRUCTED WETLAND FOR WASTEWATER TREATMENT IN RURAL AREAS IN KOSOVO

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Abstract

Republic of Kosovo has 1,304 settlements from which only 37 are urban and 1,267 are rural. Shown in percentage only 39.2% (765,125) of inhabitants live in urban areas. The focus is to work and find the best and cheap solutions for the 60,8% (1,173,370) of inhabitants of the country which live in rural areas. From this number only 42% of them have access to the sewage network while 60.8% of them have implemented individual solutions (latrines) without any treatment, leading to a large pollution of the water bodies. The existing rural sewage networks are built only with septic tanks, poorly designed and do not fulfill the wastewater treatment criteria. Regarding this issue, the Kosovan legislation concerns only urban areas (settlements of more than 2,000 inhabitants) and is expected to be completed in 2014 for rural areas according to the EU directive for wastewater discharge. As a pilot project, the CDI started with Waste Water Treatment Plants (WWTP) based on the Vertical Constructed Wetland option (French model) as it appears to be the most adapted option in this rolling, rural, and temperate climate context, implementing this kind of treatment in 3 villages for the first time in Kosovo. Through this, it is interesting to take a perspective on all the phases of these projects starting from feasibility reports, project design to concept and modalities of implementation and options for operation and maintenance, in order to assess how this technical option is feasible and replicable in the country at a large scale. It finally appears that the potential for constructed wetland in the Balkan region is promising as it provides a simple solution for most of the regional constraints, but requires skills to be developed locally for designing and building as well as a deeper consideration in the national regulation.

Keywords: Sanitation, Waste Water Treatment Plants (WWTP), Constructed Wetland, Sewage, Eastern Europe, Balkans

1.INTRODUCTION

The Republic of Kosovo has important similarities with many Eastern European countries and particularly with the entire Balkan region. The recent history led to a centralized administration of the country, including water and wastewater management. Each Municipality has its own Regional Water Company in charge of water and sanitation in a large perimeter around the town. According to the historical regulation, every village of Kosovo depends on a Municipality and its wastewater is supposed to be collected to the wastewater treatment of the main town, no matter the length of pipe and the number of pumping stations required. As this option is very expensive and is often subject to technical problems (like collecting a lot of ground water), the villages of Kosovo usually discharge wastewater in the closest water body.

In addition, the environmental standards of the European Union (EU) are targeted by the national authorities. As a baseline requirement, the Kosovan administration requests water discharge matching the EU standards for > 2000 Population Equivalent (PE) treatment plants (Kosovan Instruction N° 13/2008 providing the "limited values of the effluents that discharged on water bodies and on the system of public canalization"), what would be also requested for villages < 2000 PE treatment plants (table 1).

Since the end of the 1990's after the war, Kosovo has benefited from numerous financial supports helping to improve different sectors, including water, sanitation and environment. As a consequence, CDI (2011, 2012, 2013), with the support of the Swiss cooperation, has been involved in the general assessment of the water and sanitation situation in the country and in the strategic planning of the sector, and led some important implementation as well as pilot projects. This paper aims to present lessons learnt from the implementation of the first wastewater treatment plants in the rural area in Kosovo. The technical option appearing to be better adapted to the context is the Constructed Wetland as it complies with most of the important constraints.

Parameters	Recollection	Minimal percentage of the reduction	Measurement referent method
Bio-chemical consumption of the oxygen (**SHBO$_5$**) në 20 °C pa nitrifikim	25 mg/l O_2	70 – 90	Homogenized, non filtration and non decanted sample Determination of the treated oxygen before and after 5 days inkubimi in 20 °C +/- 1 °C, on full dark.
Chemical consumption of the oxygen (**SHKO**)	125 mg/l O_2	75	Homogenized, non filtration and non decanted sample. Oxidation with dichromate potassium (the method f digestion for 2 hours).
Total removal of the solid	35 mg/l (More than 10000 nj.p.) 60 mg/l (2 000 – 10 000 nj.p.)	90 (More than 10000 nj.p.) 70 (2 000 – 10 000 nj.p.)	Filtration of a presented sample across a filtration membrane (0, 45 μm, gravimetrical method. Drying in 105 °C and weighing. Centrifuge of a presented sample (for at least 5 min me akselarim from 2 800 until in 3 200 g), drying in 105 °C and weighing.

Table 1. The indicators of limited values for urban wastewater to be discharged from the treatment plants to the receiving bodies (Government of Kosovo, 2008)

2.METHODS

CDI has been focusing its activities on Kosovo strategic sanitation since 2011, analyzing the Kosovan water and sanitation situation. In 2011, CDI studied wastewater treatment options which exist in different Western European countries and organized a study tour in France where different treatment systems were visited in French villages (waste stabilization ponds, vertical and horizontal constructed wetlands, activated sludge reactors, trickling filters, digestors). During the tour, Kosovan authorities and Regional Water Companies representatives had the opportunity to meet many French operators, experts and authorities. This assessment led to define main pro and cons of the existing wastewater technical options in a very practical way, leading to preselecting adapted options. Back to Kosovo, 3 villages have been selected to implement the pilot project based on the lessons learnt from the other countries. In order to analyze the suitability of the preselected options, feasibility studies were done in the 3 villages., The most adapted option was selected according to the following criteria: affordable investment cost, affordable operation & maintenance (O&M) cost, low O&M skills, land availability, achievement of the EU standard for wastewater discharge (table 2), local acceptance and predilection by the local authorities and Regional Water Companies. These 3 villages are 1-Village Ternavc (Skenderaj Municipality – 700 inhabitants), 2- Village Komogllava (Ferizaj Municipality - 1,800 inhabitants), 3- Village Muhlan (Suhareka Municipality – 700 inhabitans). 2 villages were selected for implementing the infrastructures (Ternavc and Komogllava). The detailed design was done, the wastewater treatment plants were constructed and started working.

3.RESULTS AND DISCUSSION

3.1.General Water and Sanitation Situation in Kosovo

The water and wastewater sectors in Kosovo are typical for the Balkan region. Republic of Kosovo has limited water sources (surface and underground water). Rational exploitation and protection of water sources is more than crucial for sustainable economic development of the country. On the average, annually from the rivers of Kosovo there flows approximately 3.6 x 109 m^3, respectively 121.2 m^3/sec. From all rivers, the volume of accumulated water is 569,690,000 m^3, or 15.7% of all derive water. There are five big artificial lakes (Batlava, Badovc, Gazivoda, Radoniq and Prelepnica) which supply big cities of Kosovo and also some small natural lakes, without any importance for water supply of population. Around 78% of total population of Kosovo has access to drinking water systems (CDI, 2011).

The situation with the wastewater is even worse. Only 65% of the population has access to the sewage network. Focusing on rural areas, from 1,267 villages only 8 of them have constructed wastewater treatment plants. All other villages discharge wastewater into water bodies without treating it, or at the best pre-treating it with poorly designed septic tanks. 60.8% of them implement individual solutions without any treatment (CDI, 2011).

This situation can be explained by the historical planning, aiming to connect every village to the wastewater treatment plant of the main town. This historical planning turns out to be unaffordable due to the cost of the sewer system, and also generates significant O&M problems, like treatment problems due to the collection of the ground water in the sewer. The historical regulation allowed building wastewater treatment systems at a village level, that is a standard design septic tank which does not take into account the size of the village and the real amount of water. As a consequence, the few existing septic tanks in villages are under-designed. In addition, the faecal sludge was never or hardly ever extracted, leading to an insufficient functioning. For instance, the septic tank at the sewer of Ternavc was examined in August 2012: the river was very polluted by the sewer from the discharge point and at least 200 m further: there have been observed grey biomass development and septic odors. The color of the river water was grey and dark (CDI, 2012).

The feasibility studies of the 3 villages (CDI, 2012) demonstrate the following points:

- An important rate of clear water in the existing sewers, as these sewers cross the ground water table or go along small rivers and ditches. The flow measurements made in summer time showed a clear water rate of about 100%.
- Villages are subject to a peak of population in summer (population sometime doubled), due to Kosovan people living abroad coming back for holidays.
- Slope is most of the time available downstream the villages (2 m slope in Komogllave to 8 m in Ternavc)
- Land is available, but negotiations are required with the owners as well as an heavy public compensation procedure

3.2.Wastewater Treatment Options Analysis and Options Selection

Table 2 summarizes the analysis of the main treatment characteristics existing in Europe (adapted from Berland, 2001). As affordability for both investment and O&M is required in the Kosovan context as well as low O&M skills, extensive treatment technologies were chosen for a deeper analysis in the selected villages. In addition, land is available in most of the villages.

	Technology	Costs (capital)	Costs (O&M)	Land requirement	O&M requirement
		EUR/cap	EUR/(y.cap)	m^2/cap	
Intensive treatment	Activated sludge	230 €	11.5	0.2	High technical know-how
	Trickling filter, rotating biological contactor	180 €	7	0.04-0.18	High technical know-how
Extensive treatment	Constructed wetland (horizontal)	100 €	3	5	Simple operation
	Constructed wetland (vertical)	100 €	3	2-2.5	Simple operation
	Waste stabilization pond system	90 €	2.5	10	Simple operation
	Aerated pond	110 €	4	1.5-3	Simple operation

Table 2. Main characteristics of intensive and extensive treatments

The feasibility study for the 3 villages was focused on the following 5 low-cost options:

- Vertical constructed wetland (primary treatment only) (V)
- Vertical constructed wetland combination (primary and secondary treatment) (V+V)
- Vertical constructed wetland and Horizontal combination (V+H)
- Anaerobic baffled reactor combined with Horizontal constructed wetland (ABR + H)

- Ponds system

The main characteristics of these options are summarized in the multi-criteria analysis table 3.Their main distinctive features are listed below:

- Vertical Constructed Wetlands appear to be the best adapted option, as it complies with acceptable costs, low skills for O&M, and high hydraulic acceptance and safe treatment level complying with EU standards. This option is also suitable for temporary loading peaks in the summer, when the reeds are well developed (Groupe macrophytes, 2005).
- Ponds system is the most affordable option for capital and O&M costs. It also well adapted to high hydraulic rate and clear water acceptance. But the land requirement would make the procedure of land acquisition difficult. In addition faecal sludge appears to be difficult to extract.
- As a primary treatment, septic tanks, ABR and Imhoff tank are not very well adapted to high hydraulic loads and hydraulic peaks (Foxon, 2009).
- As a secondary treatment, horizontal constructed wetlands are not adapted to variable hydraulic loads or have to be designed accordingly, but present the advantage to require smaller slope.

Finally, the selected option were Vertical constructed wetland combination in Ternavc with a gravitary functioning (no pump), and a Vertical and Horizontal combination for Komogllave (as the slope is smaller). The construction phase reveals that constructed wetland construction required skills. Trainings and controls of the construction company are essential. Designing with safety is a lesson learnt (for instance slope > 1% for the pipes ; gravel layer thickness > 10 cm in the constructed wetlands). All the material needed for the construction is available in Kosovo, except for the flushing mechanisms that was ordered aboard (but could be now replicate by Kosovan manufacturer).

Type	Total surface	Topo delta	Efficiency on the liquid fraction	Sludge production	Hydraulic robustness	O&M skills	Capital cost Euro/cap	O&M cost Euro/ (y*cap)
V	2 m^2 /cap	2-3 m or pump	Medium and safe Nitrification	Solid and humified Each 10 year	Yes	Simple but frequent	100	1.55
V+V	2.5 m^2 /cap	3-5 m or pump	Good and safe Nitrification	Solid and humified Each 10 year	Yes	Simple but frequent	170	1.80
V+H	3 m^2 /cap	2-3 m or pump	Good and safe Denitrificati on	Solid and humified Each 10 year	No	Simple but frequent	190	1.70
ABR+ H	5 m^2/cap (low Temp)	1 m	Good according to Temp.	Liquid sludge Each year	No	Simple Further managem ent required for sludge	nd	nd
Ponds syste m	15 m^2 /cap	0.8 m	Medium, according to season	Liquid sludge Each 10 years	Yes	Simple Sludge difficult to extract	75	0.45

Table 3. Multi-criteria analyze of the pre-selected options

3.3.Description of the selected option for Ternavc: Vertical + Vertical Constructed wetland

According to Molle (2005), a vertical constructed wetland is made by filters that are planted with aquatic plants. There are several filters filled with successive layers of gravels and used each 3-4 days. Waste water is flushed onto the wetland surface from above using a gravidity flushing system or a pump. The water flows vertically down through the filter matrix. Suspended solids are mostly filtered on the surface where they get dried and humified, turn into biosolids. While flowing through the filter, the liquid fraction is subject to a physical (filtering) and a biological (aerobic biomass attached to media) treatment. The treated water is drained and discharged to the river or to a secondary treatment according to the requirements.

1st stage vertical constructed wetland itself requires a surface of 1.2 m^2/capita divided into 3 filters and a 2 m slope, approximatly. The exact slope needed depends on the dimmenisons of the filter. If slope is not available, thus pump is needed. The treatment level achieved is 80 % COD removal and 90 % SS removal.

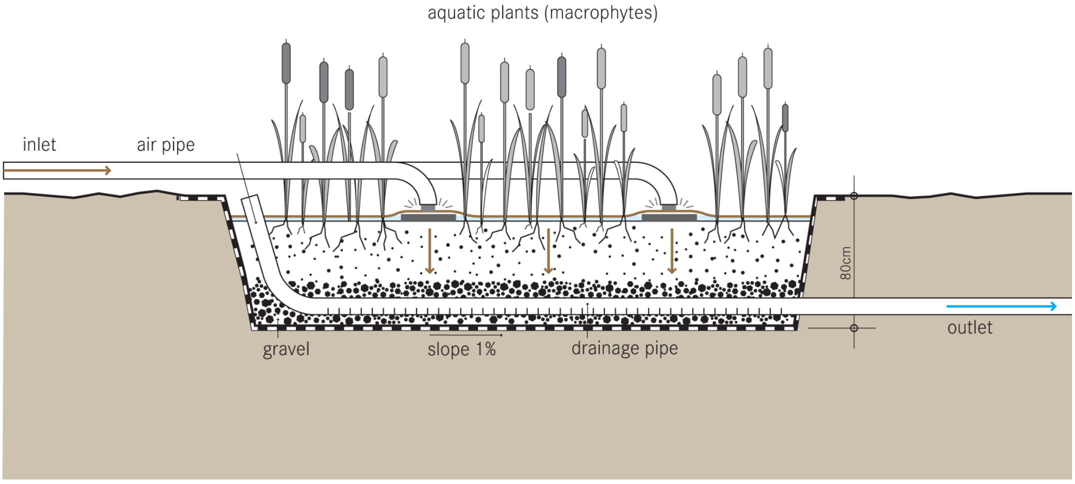

Figure 3. Longitudinal section of vertical constructed wetland (Tilley *et al.,* 2008)

Figure 4. 1st stage Vertical constructed wetland inFrance (photo PH Dodane, 2010)

2nd stage vertical constructed wetland requires an addituional surface of 0.8 m^2/capita diveed into 2 filters and a 2 m slope, approximatly. The exact needed slope depends on the dimmenisons of the filter. If slope is not available, thus pump is needed. The treatment level achieved for the combination of 2 vertical constructed wetland is more than 90 % COD removal and 95 % SS removal, leading to a 25 mg/L BOD_5 max for the discharged effluent.

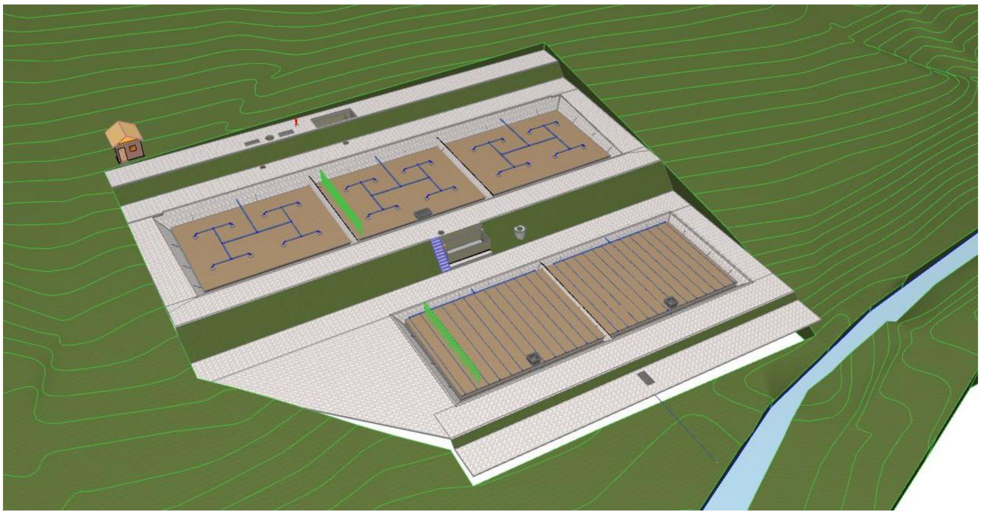

Figure 5. CDI detailed design 3D drawing (general view)

Figure 6. 2nd stage vertical constructed wetland, France, Winter 2004 (photo P-H Dodane)

3.4.Description of the selected option of Komogllave : Vertical + Horizontal constructed wetland

Principle is to combine a first stage vertical constructed wetland with a second stage horizontal. According to (Diederik et al., 2004), horizontal constructed wetland is a filter saturated with water. The effluent is spread out over the inlet. Then it flows horizontally through a fine gravel substrate. Water goes out in a drain located at the opposite end of the bed. This drain is connected to a manhole that allows the water flow to be adjusted.

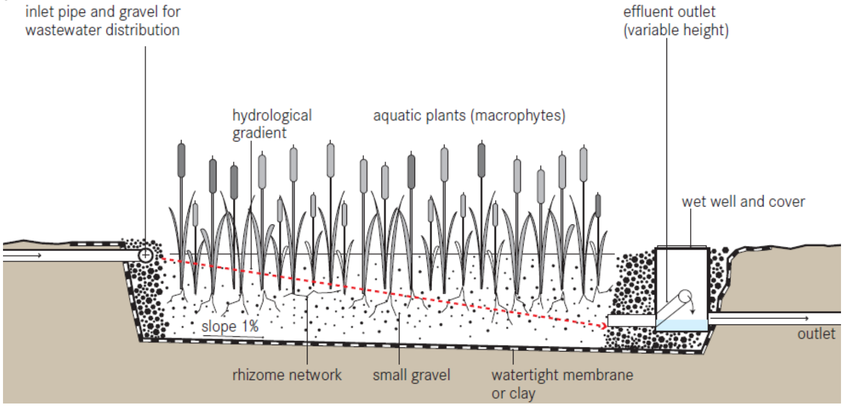

Figure 7. Section of a horizontal constructed wetland combination (Tilley *et al*., 2008)

Figure 8. Horizontal constructed wetland with young reeds, Moldova, 2010 (photo P-H Dodane)

2nd stage horizontal vertical constructed wetland requires an additional surface of 2 m2/capita approximatly and a 1 m slope. The exact surface depends on the treatment requirement and the gravel used in the filter. The treatment level achieved for the combination of 2 vertical constructed wetland leads to a 25 mg/L BOD_5 for the discharged effluent.

5.CONCLUSION

From the implementation of 2 wastewater treatment plants technology in the rural village, it can be concluded that the vertical constructed wetland technology offers the best advantages in the context, complying with the constraints of high hydraulic loading rate, population peak in the summer, treatment removal according to the EU standards, affordability, low O&M skills, and good acceptance by the local authorities and Regional Water Companies. Vertical primary stage can be combined with horizontal constructed wetland when the slope is too low; whether the hydraulic design considers the clear and the rain water collection.

In Kosovo rural area, this option is very promising, as 440 out of the 1,267 Kosovan villages have very suitable parameters for Vertical constructed wetlands, functioning by gravity (without pump, lowering the O&M cost and skills). Theses mountain villages have good slope, large public lands and are too far from the main towns to be connected to the town network. The treatment potentially concerns more than 200,000 capita (table 4).

Table 4: Villages with suitable parameters for constructed wetlands by gravity in Kosovo

Nr	Municipality	Nr. of villages	Nr. of capitals	Nr	Municipality	Nr. of villages	Nr. of capitals
1	Dragash	21	11,325	17	Obiliq	2	1,795
2	Prizren	32	15,616	18	Podujeve	21	1,070
3	Suhareka	16	7,424	19	Prishtine	8	4,330
4	Malisheva	19	9,930	20	Shtime	11	6,845
5	Gjakova	34	18,868	21	Graqanice	2	1,075
6	Rahovec	9	4,522	22	Gjilan	7	3,605
7	Decan	14	8,746	23	Kamenica	22	6,890
8	Istog	19	10,567	24	Viti	12	6,057
9	Klina	22	11,343	25	Ranillug	3	985
10	Peja	27	18,115	26	Novoberdo	20	5,324
11	Vushtrri	21	11,237	27	Kacanik	21	10,600
12	Skenderaj	23	14,769	28	Ferizaj	1	1,300
13	Mitrovice	18	9,030	29	Shterpca	7	4,803
14	Gllogovc	9	7,711	30	Hani i Elezit	8	2,905
15	Fushe Kosove	2	1,138		TOTAL	**440**	**223,755**
16	Lipjan	9	5,830				

It is now essential to be successful in the functionning of the treatments plants (starting phase with the acclimataton and growth of the reeds, hydraulic adjustment and O&M) the 2 first constructed wetland in the country in order to build local capacity for all stakeholder and to convince and generating useful practical and instutional changes at the regional and national levels.

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