REED BED TREATMENT SYSTEMS AS AN AFFORDABLE AND RELIABLE OPPORTUNITY FOR SOLVING SANITARY EMERGENCIES IN DEVELOPING COUNTRIES WITH TROPICAL CLIMATE

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introduction

In this paper, we present the 11 months performance of a pilot Reed Bed Treatment System (RBTS), located in the city of Nacaome, Dept. of Valle, Honduras. Recommendations for the optimal design for tropical climate RBTS are also provided.

The project is developed inside the IDEASS (Innovations for development and south-south cooperation) initiative, that is promoted by the international programmes OIT/Universitas, PNUD/APPI and PNUD/IFAD/UNOPS. These programmes together with national politics favour local development processes with an integrated and participated approach, with the participation of public and private stakeholders and of the civil society. The principal aim of IDEASS is to promote innovative technologies and experiences that showed to contribute to human development, to reduce exclusion, unemployment and poverty.

Considering its large experience in sustainable waste water treatment and in the belief that in Developing Countries the necessity of adapting low-tech systems with both easiness of management and high purification efficiency is even stronger than in our Countries, the Environmental Protection Agency of Tuscany (ARPAT) joined the project bringing technical support.

The main objective of the project was to test the efficiency of the RBTS as a sustainable, low-cost, low-tech approach to improve current sewage management and hygienic problems in Honduras, and in Developing Countries in general.

In this case the first step was the realization of a pilot scale system with demonstrative characteristics for the treatment of waste water so to:

- show that constructed wetland, that are broadly applied in western Countries since 20 years, are a sustainable technology both from ecological and economic point of view;
- verify appropriate design according to local conditions so to optimize economic resources for the large scale realization;
- favour actions that stimulate water saving and reuse of treated water;
- start actions for the formation of local technicians.

Achievement of these goals have been verified through a monitoring program made by Universities, Research Institutes and local agencies and coordinated by ARPAT, and through the exchange of technical know-how with experts on natural depuration of waste water connected with ARPAT.

The pilot scale RBTS has been realized in the city of Nacaome, that is located in the Department of Valle, a semi-rural area of Honduras. The Nacaome city's sewage is currently treated by two in-line lagoons realized between the end of 1996 and the beginning of 1998; the existing sewage system is under implementation. The two lagoons, fed through a pumping station, present a strong hygienic-sanitary impact (bad odours, development of insects, possible contamination of domestic animals) and poor performances, not assuring a good water quality in the receiving water body.

Water quality preservation from pollution in Honduras is regulated by law n. 058 of 09/04/1996 ("Normes Tecnicas de las descargas de aguas residuales a cuerpos receptores y alcantarillado sanitario"); principal parameters that have to be respected are reported in the Table 1.

Parameter	**U.M.**	**Limit**
BOD_5	mg/l	50
COD	mg/l	200
Suspended Solids	mg/l	100
Total Nitrogen	mg/l	30
NH_4 Nitrogen	mg/l	20
Fecal Coliform (FC)	100 ml	5000

Table 1 – Limits for waste water delivering in a water body (Tab.1 of Law n. 058 of 09/04/1996, art. 6)

methods

The pilot scale RBTS consists in a 10 m^2 horizontal subsurface flow system (HF) treating 3-chamber septic tank effluent. In the initial design, treated amount of waste water could be chosen between 0.5 m^3/d and 1 m^3/d, so to verify performances under different conditions.
The scheme of the pilot scale treatment system is the following:

- pumping station for the feeding of the RBTS, allowing the withdrawal of the desired flow from the Nacaome city's sewage system;
- primary treatment system (3-chamber septic tank);
- reed bed with horizontal sub-surface flow (2.5 length x 4.0 m width; average height of filling 0.8 m);
- level regulation and analysis well;
- discharge in the receiving water body.

Reeds that have been used, belonging to Phragmites species, were founded near the area of realization of the plant.

Figure 1 – Pilot scale horizontal subsurface flow reed bed system realized in Nacaome

In the design of the system we adopted the following data:

Parameter	***U.M.***	
Served population	p.e.	10
Specific hydraulic load	**l/person x day**	**100**
Daily average hydraulic load	m^3/d	1.0
Specific organic load	gr BOD_5/person x day	60

Daily average organic load	gr/day	600
Specific SS load	gr/person x day	80
Daily average SS load	gr/day	800
Design temperature	**°C**	**23**

Table 2 – Design parameters

The considered specific hydraulic load is significantly lower in respect to European standards: this is mostly due on one side to the poor availability of water that characterizes the region, and on the other side to the different hygienic habits of people. Though low, specific hydraulic load allows the presence of acceptable hydraulic retention times (2.3 days). Design temperatures reflect the tropical climate of the area: one of the project's own aims was to test the reliability of reed bed design based on low surface coefficients (1-2 m^2/p.e.) in presence of high and through-year constant temperatures (Mandy et al, 1998, Diemont, 2006).

The monitoring program started on the 4th of November 2004 and ended on the 7th of October 2005, for a total of 19 analyzed samples. Since the first measurements, very good performances of the system were observed: this brought to suppose that low m^2/p.e. coefficient could be adopted. Therefore, during all the period of monitoring, inlet waste water flow was fixed at 1.0 m^3/d.

results and discussion

During all the monitoring period, outlet values have been constantly lower than limits imposed by Honduran laws.

PARAMETER	MEASURE	LAWL LIMIT	INLET	OUTLET	REMOVAL%
Chemical			***19 samples - mean value***	***19 samples - mean value***	
COD	mg/l	200	312	66	78.79
BOD_5	mg/l	50	80	15	81.22
Total Nitrogen	mg/l	30	22	6	72.78
Nitrites	mg/l	-	-	-	-
Nitrates	mg/l	-	2	1	33.31
NH_4	mg/l	-	-	-	-
Total Phosphorus	mg/l	5	6	5	22.84
Anionic surfactants	mg/l	-	-	-	-
Physical					
Temperature	ºC	< 40	32	30	5.93
Turbidity	NTU	-	884	155	82.50
Conductivity	µS/cm	-	669	915	-
pH		6 to 9	9	7	17.77
Totali Suspended Solids	mg/l	100	157	12	92.10
Dissolved Oxygen	mg/l	-	-	-	-
Bacteriological			***15 samples***	***15 samples***	
Total Coliform	units/100 ml	-	104450	2671	97.44
Fecal Coliform	units/100 ml	5000	50313	1316	97.38
Microalgal residual	cels/ml	500 - 2000	-	1540	-

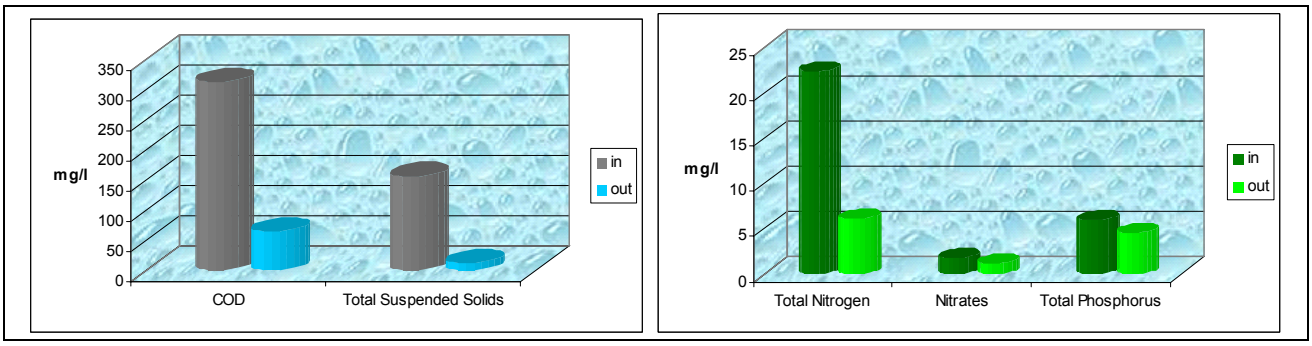

Table 3 – Monitoring program results (average values)

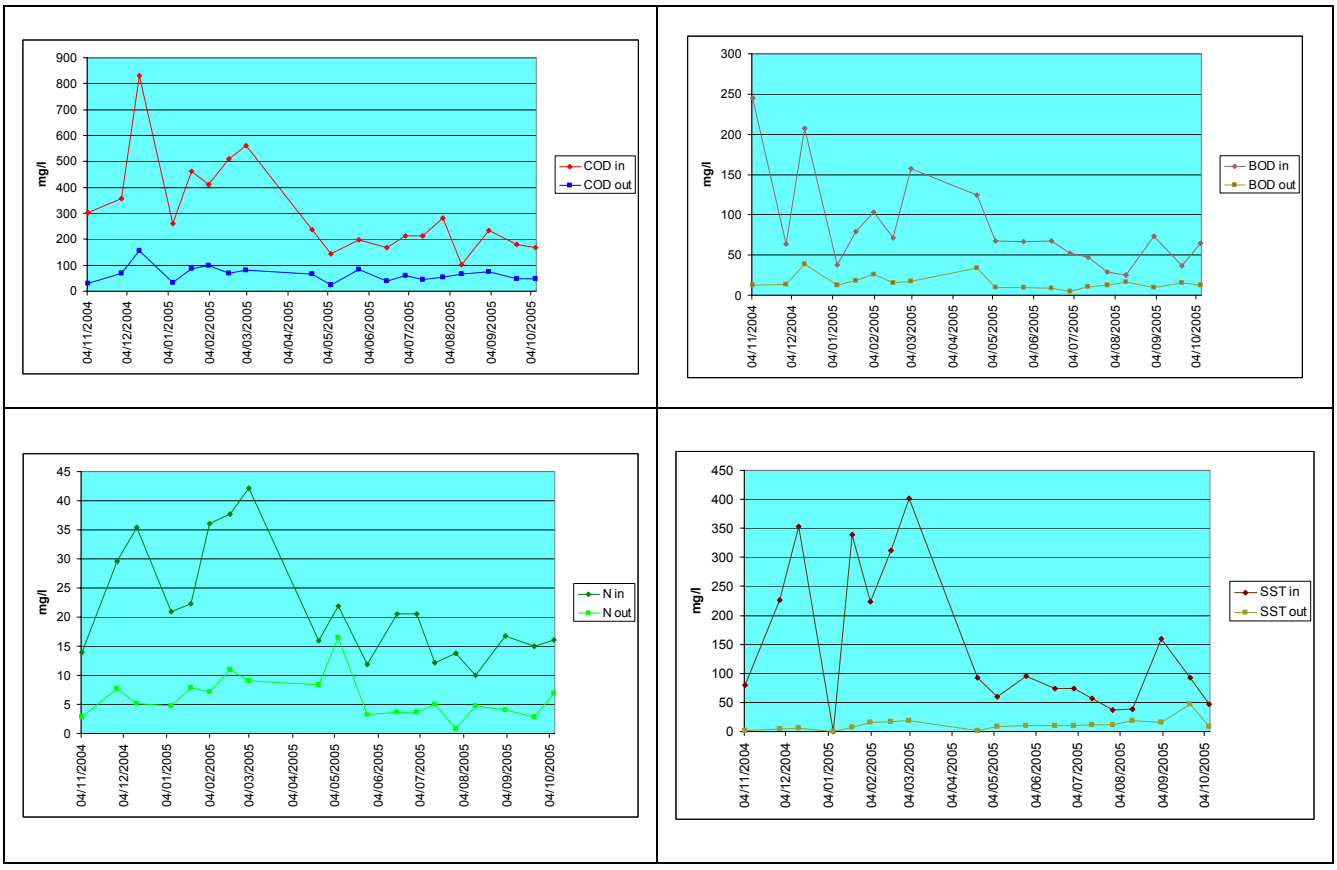

Figure 2 – Trends of principal inlet and outlet parameters observed at the pilot scale RBTS in Nacaome

During the period of monitoring, the RBTS was operating at a relatively constant temperature of 28-30°C. The removal rates were high for organic content and TSS (respectively >80% and >92%), even with a shorter HRT (2.3 days) and in spite of strong fluctuations in inlet concentration values.

In particular, from measured data we can see that the removal rate for organic content is substantially unrelated with temperature: in fact, observed removal rates do agree with values indicated in literature (EPA, 1999) for plants operating with similar HRT but at strongly colder climates.
It is important to notice that the percentage removal rate of organic load is constant against the variation of inlet concentrations, also for very low values: this fact agrees with previsional models commonly used in the design of horizontal subsurface flow constructed wetland systems (Reed et al. 1996, Kadlec & Knight 1996).

Also the removal rate for suspended solids is high (up to 96%), with maximum outlet values of 15 mg/l.

Nitrogen removal rates (average value 72%) are significantly higher than average values usually observed in HF systems operating with similar HRTs; this is due to two different facts:

- during the first year of operation, HF systems present higher nitrification rates (F. Masi et al, 1999);

- tropical climate conditions (inlet and outlet water temperature ranges from 28 to 32 °C) strongly favour the development and the activity of nitrifying bacteria.

A two fold reduction for hygienic parameters (Total Coliform (TC), Faecal Coliform (FC)) has been reached throughout the whole monitoring period, with maximum values of around 5000 FCU/100ml TC in the outlet.

conclusions

The horizontal flow constructed wetland has shown acceptable and promising performances throughout the investigation, with effluent pollutant concentrations largely below the Hondurans limits for discharge in fresh water.
The RBTS demonstrated high removal efficiencies for organic content, nitrogen, and TC/FC, with an aerial coefficient as low as 1 m^2/p.e. and a HRT of 2.3 days. This confirms the effectiveness of constructed wetland systems for the treatment of waste water and offers the real possibility of realizing full scale plants with a total surface smaller than European standards.
This treatment capabilities, along with the use of low-cost construction techniques and local materials, meets the stringent requests often founded in Developing Countries for a quick resolution of sanitary emergencies in presence of a lack of available economical resources.

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