

# A MULTISTAGE CONSTRUCTED WETLAND FOR WASTEWATER TREATMENT OF SMALL RURAL AGGLOMERATION IN TUNISIA

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## Abstract

This paper presents the results obtained on a Wastewater Treatment Pilot Plant (WWTPP). The WWTPP erected at Chorfech (rural settlement of 50 houses counting 350 inhabitants) consists of one Imhoff tank for pre-treatment, and three stages in series: a first, horizontal subsurface flow constructed wetland (CW) stage, a second subsurface vertical constructed wetland flow stage, and a third horizontal flow CW stage. The mean overall removal rates performed by the WWTPP of Chorfech during the monitored period have been respectively as 97.12% for TSS, 94.56% for COD and 97.22% for BOD5, 71.39% for total nitrogen, and 82.15% for total phosphorus. The removal of the *E. coli* and *Enterococcus* by the whole system was ranged from 1 to 2.5 log units respectively.

**Keywords:** Constructed wetland, Small settlement, Sustainability; Wastewater treatment.

## Introduction

In Tunisia, 40% of the population resides in rural areas in small village or isolated habitat with an access to drinking water for almost of them. 83% of this population stay in the poor sanitation services and their wastewaters was discharged directly without treatment. Only 3.2% of the rural populations have a sewerage system without treatment; and 13.5% having a sanitary pit or septic tank (Sellami et al., 2007). For these reasons, a few experiences were conducted in Tunisia by researchers to identify the best wastewater treatment technology for the small settlements (Sellami et al. 2007; Lahjouj et al., 2007; Kouki et al., 2009). The technology must be robust, simple and low-tech as possible, and need to guarantee a very high water quality at the discharge point as requested by the stringent Tunisian regulation for release of treated wastewater into water bodies, which is unavoidable at least during certain periods of the year. Constructed wetland (CW) systems can play this role and have proven to be a good technology, ensuring appropriate performances even with a low technical profile in the wastewater management for villages and small communities (Masi et al. 2010).

The purpose of this study is to present the WWTPP of Chorfech (small rural village) using a constructed wetland combining horizontal and vertical flow for wastewater treatment. The design of the plant was developed in consultation with the community, local and national authorities by a team of experts in a project for sustainable water management.

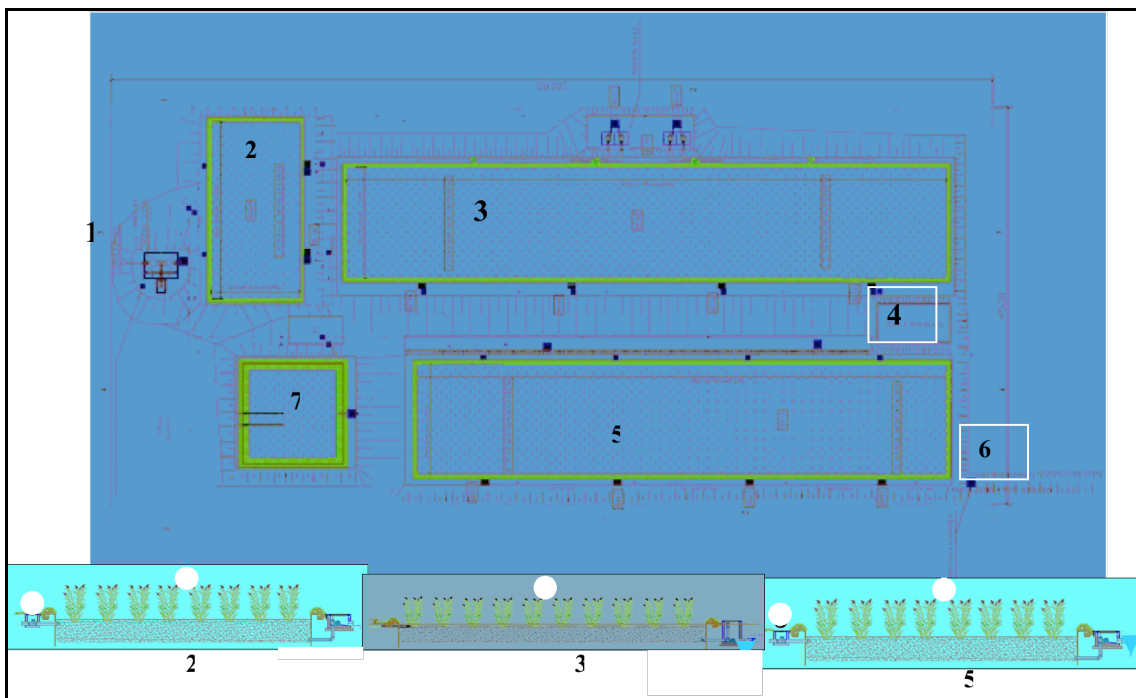
## Methods

### Constructed Wetland System (WWTPP)

Chorfech 24 is a rural settlement (350 inhabitants live in about 50 houses) situated about 24 km Northwest of Tunis (36°57'11,33" N, 10°03'59,66" E). Before the realisation of the Wastewater Treatment Pilot Plant, the raw wastewater collected in the conventional sewage network linked to a septic tank, was discharged directly into a drainage channel. The daily wastewater flow is about 17 m<sup>3</sup>. Figure 1 presents the general layout of WWTPP of Chorfech. The wastewater, after a primary treatment in the Imhoff tank, flows into a first submerged horizontal flow constructed wetland as secondary treatment (1<sup>st</sup> stage), then into a vertical flow constructed wetland (2<sup>nd</sup> stage) and into a second horizontal flow constructed wetland again (3<sup>rd</sup> stage). Depending on the objectives of treatment, reuse or discharge into the channel, it is possible to skip the 3<sup>rd</sup> stage and to stop treatment at the level of the 2<sup>nd</sup> stage for conservation of nutrients (nitrogen and phosphorus) for irrigation; in this case, the treated wastewater is stored in a reservoir for reuse.

### Monitoring and measurements of the water quality parameters

The influent and effluent water samples were monitored periodically. Physical chemical and microbiological analyses were performed on the same day according to the Standard Methods (APHA, 1999). pH, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), phosphate (PO<sub>4</sub><sup>3-</sup>-P) and Total Nitrogen (TN) were monitored.

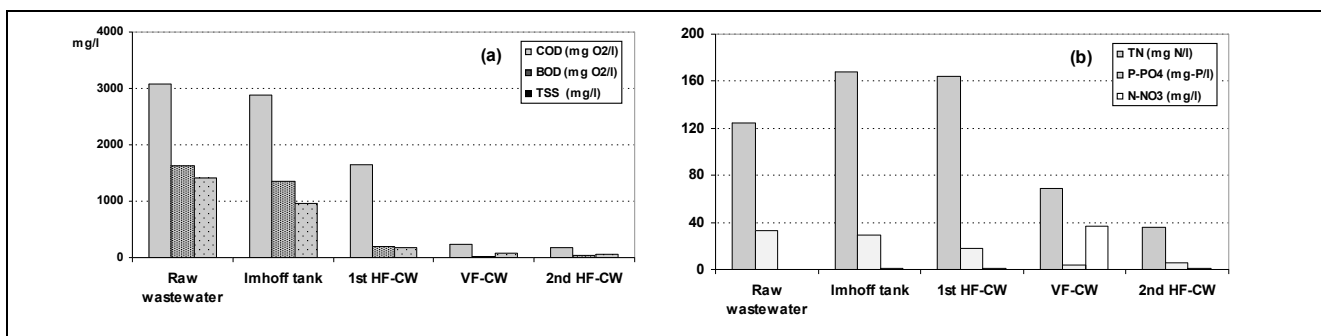


**Figure 1:** General layout of WWTPP, Chorfech 24

1: Imhoff Tank; 2: 1<sup>st</sup> stage HF-CW; 3: 2<sup>nd</sup> stage VF-CW; 4: Reservoir of treated wastewater; 5: 3<sup>rd</sup> stage HF-CW; 6: Treated wastewater outlet to the drainage channel; 7: Sludge composting bed CW.

## Results and Discussion

The mean overall removal rates performed by the WWTPP of Chorfech 24 during the monitored period have been respectively 97% for TSS and BOD, 95%, for COD, 71% for TN, and 82% for phosphorus (P-PO<sub>4</sub>). Compared to the literature, these rates remain high, independently of the quality of the final effluent. In Fig. 2(a); it can be noticed that the main part of COD reduction takes place in the 1<sup>st</sup> and 2<sup>nd</sup> stages (HF-CW and VF-CW). The most important part of TSS removal is achieved by the Imhoff tank and the 1<sup>st</sup> stage (HF-CW).



**Figure 2:** Parameter reductions of (a): COD, BOD and TSS and (b): TN, P-PO<sub>4</sub> and N-NO<sub>3</sub>.

The concentration of TSS at the entrance of the 1<sup>st</sup> HF-CW remains high and could clog the bed in the long term. The load applied to the overall system ranged between 1.13 and 27, with an average equal to 12.7 g BOD<sub>5</sub>/m<sup>2</sup>.d. According to the average the applied load may still be compared to load rates cited in the literature. In a comparative study conducted by Puigagut et al. (2007) on constructed wetlands for small communities in Spain there is a variability in the applied organic loads. The VF-CW systems present the highest rates of all the types of systems analysed with a range of 22.8–29.8 g BOD<sub>5</sub> m<sup>2</sup>/d. These are followed by the HF-CW and the combined systems (HF-CW in combination with other processes). The reduction rates of macronutrients (nitrogen and phosphorus, Fig. 2(b) or rather the concentration at the outlet of the system is insufficient compared to the Tunisian norms authorizing the discharge of treated wastewater into receiving waters. Biogeochemical cycling of nitrogen in treatment wetlands is complex involving inter conversions between different N species and transfers between storage compartments. Kadlec et al. (2005) demonstrated that the details of nitrogen in constructed wetlands include strong interactions between water, sediment and biofilm solids, and plant storage of nitrogen. The abiotic adsorption of phosphorus to the substrate has been reported as the major P-removal mechanism in constructed wetland by several researchers. Various physical-chemical properties including pH, redox potential, dissolved ions, calcium content, amorphous and poorly crystalline Al and Fe-oxides content of these substrates influence the P-sorption mechanisms onto their surfaces.

## Conclusion

The result obtained show the feasibility of the system and the WWTPP seems to be the most powerful combination coupling the horizontal and vertical submerged flow constructed wetland after Imhof tank. The load applied to the all system ranged between 1.13 and 27.38, with an average equal to 12.75 g BOD/m<sup>2</sup>.d. The mean overall removal rates performed by the WWTPP of Chorfech during the monitored period have been respectively as 97.12% for TSS, 94.56%, for COD and 97.22% for BOD<sub>5</sub>, 71.39% for total nitrogen, and 82.15% for total phosphorus.

The WWTPP implemented in Chorfech, is mainly meant as a demonstration of sustainable water management solutions (low-cost wastewater treatment). The pilot activity should also meant to help gain experience with the techniques implemented and improve them if necessary until they could be recommended for wide application in rural settlements in Tunisia and similar situation in the world.

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