IWA Specialist Conference on
Wetland Systems for Water Pollution Control
30 September – 4 October 2018, UPV, Valencia, Spain

Towards dimensioning guidelines for raw wastewater treatment in a single stage French System treatment wetlands in arid climate of Peru

Höllmann, M.*; León, M. V. A.; Barjenbruch, M.; Hoffmann, H.; Platzer, C.; Miglio, T.R**

* TU Berlin, Department of Urban Water Management, Gustav-Meyer-Allee 25, 13355 Berlin, maxhoellmann@web.de
** Universidad Agraria La Molina, UNALM, Dpto. Ordenamiento Territorial y Desarrollo Sostenible, Av. La Molina s/n La Molina, 15024 Lima, Peru, vladimirmenacho@gmail.com

Abstract: The performance of the first stage of the French System was studied on a pilot plant operated during 5 month in Lima, Peru with real wastewater from the public sewer system. The aim was to optimize raw wastewater treatment in a single-stage system under warm and dry climatic conditions. The surface of the planted filter was divided in two sub-units, which were operated alternately during 72 hours. COD loads of up to 442 g m^{-2} d^{-1} in combination with TSS loads of up to 552 g m^{-2} d^{-1} (based on surface area of the active sub-unit) were treated with efficiencies above 90%. The performance of the filter allows the conclusion that under the given conditions usual approaches of 0.8 m² $p.e.^{-1}$ (total surface area, Molle et al. 2015) can still be reduced depending on national quality standards for treated wastewater or further treatment options.

Keywords: French System; tropical arid climate; dimensioning

Session *- Design tools and modelling*

Introduction

The French system is increasingly considered an economically interesting alternative for decentralized wastewater treatment. Studies in warm climate already proved, that only the first stage is able to treat raw wastewater with high efficiency and without or much less organic deposits from retained sludge as in colder climates. So, standards for wastewater treatment can be fulfilled with this simple, low impact technology (Manjate et al. 2015, Molle et al. 2015, Platzer et al. 2016).

The objective of this study is to identify breaking points of the hydraulic and organic load for the first stage of the French System und warm, tropical conditions in order to define dimensioning recommendations and to reduce the footprint of future projects.

Material and Methods

Investigations were carried out on a full scale pilot plant in Lima, Peru (Figure 1 and 2) to treat domestic wastewater from a municipal sewer without stormwater influence. The filter surface of the first stage of the French system is 36 m^2 divided in two sub-units of 18 m^2 each, fed in hydraulic batches of six minutes alternately for 72 h each. The filter material is gravel with grain sizes of 2–6 mm and a filter height of 0.65 m and 0.35 m of transmission/drainage layer with coarser material. A saturated layer with a height of 0.3 m was generated at the bottom of the filter. Influent and effluent samples were taken biweekly during 21 weeks from October 2017 to March 2018 and analyzed for COD, BOD_5, TSS, N_{total}, NH_4-N, and NO_3-N using standard methods (APHA 2012).

By increasing the number of daily hydraulic batches, the hydraulic load was increased in three investigation phases (six to eight weeks). Hydraulic loads of 0.12, 0.25 and 0.33 m d^{-1} were applied in phases 1 to 3, respectively.

Results and Conclusions

Influent and effluent characteristics of the filter are given in Table 1. Influent concentrations for organics and solids are high, average COD concentrations of up to 951 mg l^{-1} and TSS concentrations of up to 1040 mg l^{-1} were observed. Average effluent concentrations decreased from phase 1 to phase 3 despite increasing loads. However, due to seasonal changes, the wastewater temperature increased in each phase by about 2° C to an average temperature of 27.1 °C in phase 3.

Table 1: Influent and effluent characteristics for the three investigation phases (arithmetic mean ± standard deviation)

			COD	BOD_5	TSS		T
phase 1	N*	(-)	8	2	9	(-)	12
	Influent	(mg l^{-1})	523 ± 74	274 ±77	466 ± 446	(°C)	-
	Effluent	(mg l^{-1})	94 ± 53	43 ±13	18 ±12	(°C)	23.4 ± 0.8
phase 2	N*	(-)	14	5	14	(-)	16
	Influent	(mg l^{-1})	828 ± 261	542 ±10	540 ± 245	(°C)	-
	Effluent	(mg l^{-1})	96 ± 15	38 ±15	17 ±15	(°C)	25.5 ± 1.0
phase 3	N*	(-)	11	4	11	(-)	14
	Influent	(mg l^{-1})	951 ± 251	450 ± 68	1040 ± 404	(°C)	-
	Effluent	(mg l^{-1})	85 ± 18	31 ± 4	14 ± 12	(°C)	27.1 ± 0.9

* N: number of samples

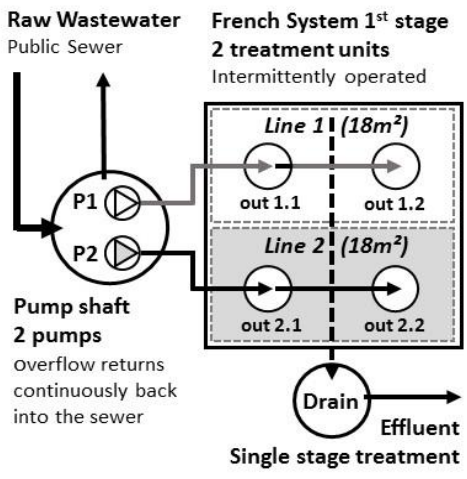

Figure 1: Pilot plant conception for Single Stage treatment of raw wastewater in Lima/Peru

Figure 2: Foto of Pilot plant with samples of Raw Wastewater and Effluent of the 1st stage of the French system during the presented investigation, phase 2

Figure 3 shows the applied and removed loads on the active filter unit for COD and TSS, which were observed in this study. The results are compared with design loads for the first stage of the French System in tropical regions, recommended by Lombard Latune and Molle (2017).

Applied COD loads vary from 52 to 442 g m^{-2} d^{-1} (related to active area, see figure 1) with an average treatment efficiency of 87 %. The efficiency is constant in the observed range of applied loads, even for high values. High removal rates for COD can even be observed above the design load of 350 g m^{-2} d^{-1} recommended by Lombard Latune and Molle (2017). At an applied load of 442 g m^{-2} d^{-1} 94 % of COD were removed by the first stage of the French System.

The constant removal rates for COD suggest that loads can be further increased. The point where organic removal rates start decreasing was not reached and further investigations are necessary to find the maximum organic load that can be applied for raw wastewater treatment under the given climate conditions.

However, it has to be stated, that the highest loads in this study were applied during summer. Long-term investigations have to prove, if it only was an effect of higher temperatures and therefore faster microbial metabolism or if it is due to increasing accumulation of biomass during the start-up time and consequently should be maintained or even improved with operation time and independent of ambient temperatures.

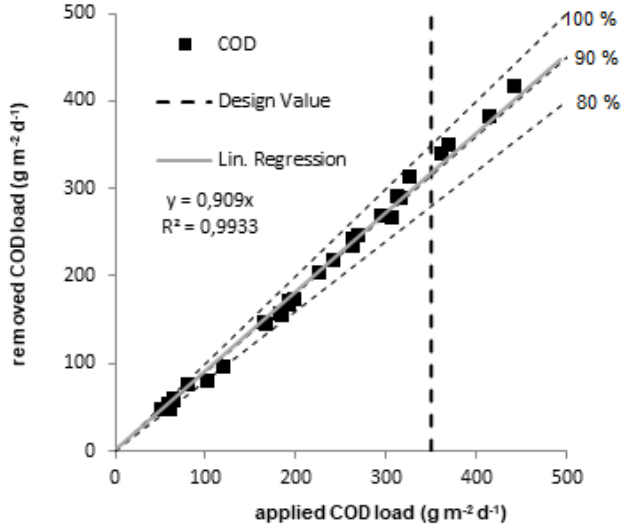

Figure 3: Applied and treated COD loads on the active filter with linear regression and suggested design load taken from Lombard Latune and Molle (2017)

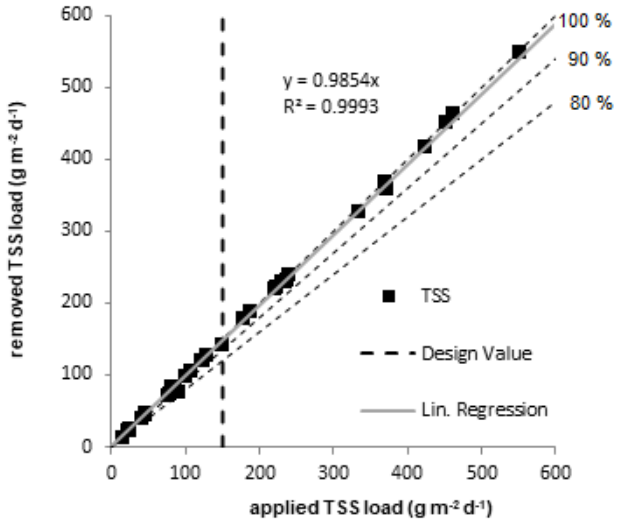

Figure 4: Applied and treated TSS loads on the active filter with linear regression and suggested design load taken from Lombard Latune and Molle (2017)

TSS removal rates are even higher than the ones for organic matter (see Figure 4). The average removal rate is 97.5 % and the efficiency never dropped below 83.9 %. 81 % of the observed values of removal efficiency are above 95 %. Stable removal rates occur up to elevated solid loads of 552 g m^{-2} d^{-1} (related to active area, see Figure 1). Due to high concentrations of TSS in the raw wastewater, the solid loads observed in this study exceeded the design value of Lombard Latune and Molle (2017) in nearly half of the measured cases and the removed loads can still be described by a

linear trend. Another important fact is, that significant build-up of a deposit layer was not observed, even at elevated solid loads because of faster and more complete mineralization of solids in warm climate (Mole et al., 2015). Thus, higher solid loads can be applied without risking a loss of removal efficiency.

Table 2 shows the influent and effluent concentrations for N_{total}, Ammonia-N and Nitrate-N. In relation to N_{total} in raw wastewater the Ammonia-N reduction (mainly Nitrification and partially plant uptake and other processes) is about 60 % and the average reduction of N_{total} is 61 %. Thus, both nitrification and denitrification take place in the system and extremely low Nitrate-N concentrations in the effluent show that the saturated bottom layer provides good conditions for denitrification.

Table 2: Influent and effluent concentrations for different nitrogen species (arithmetic mean ± standard deviation)

		Influent	**Effluent**
N_{total}	(mg l^{-1})	56 ± 38	22 ± 3
NH_4-N	(mg l^{-1})	38.3 ± 7.0	19.0 ± 2.9
NO_3-N	(mg l^{-1})	-	1.4 ± 1.1

Based on the results of this investigation on a pilot plant under climatic conditions of Lima, Peru it can be concluded, that the first stage of the French system could have a higher treatment capacity than previously known from other studies. Based on an average specific COD load of 120 g $p.e.^{-1}$ d^{-1} (DWA, 2017) and the maximum COD load treated in this study with an efficiency of 94%, would result in a specific filter surface necessity of 0.54 m^2 $p.e.^{-1}$ (total surface area, or 0.27 m^2 $p.e.^{-1}$ for the active sub-unit). However, efficiencies of high loading rates have to be investigated in long term approaches.

On the other hand, the study proved the opportunity, given by this relatively simple process, to treat raw wastewater under warm climatic conditions with a very high and stable efficiency and without sludge accumulation, Methane production or odor, know from anaerobic treatment.

References

APHA (2012), Standard Methods for the Examination of Water and Waste Water. 22nd Edition, American Public Health Association, American Water Works Association, Water Environment Federation.

DWA (2017), Deutsche Vereinigung für Wasserwirtschaft Abwasser und Abfall: DWA-Regelwerk/Arbeitsblatt 262, Grundsätze für Bemessung, Bau und Betrieb von Kläranlagen mit bepflanzten und unbepflanzten Filtern zur Reinigung häuslichen und kommunalen Abwassers.

Lombard Latune, R and Molle, P. (2017), Les filtres plantés de végétaux pour le traitement des eaux usées domestiques en milieu tropical: Guide de dimensionnement de la filière tropicalisée.

Manjate, E.S. et al (2015), First stage of the French vertical flow constructed wetland system: experiments with the reduction of surface area and number of units. *Journal of Water, Sanitation and Hygiene for Development* **5**(1): Page 50–55.

Molle, P. et al. (2015), French vertical-flow constructed wetland design: adaptations for tropical climates. *Water Science and Technology* **71**(10): Page 1516–1523.

Platzer, C., Hoffmann, H., Miglio, R. (2016), Long term experiences with dimensioning and operation of vertical flow constructed wetlands in warm climate regions of South America. *IWA Specialist Conference on Wetland Systems for Water Pollution Control*.