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Vivien Dubois, Pascal Molle

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# Onsite one stage constructed wetland fed by raw wastewater: performances and resilience of the system.

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V. Dubois<sup>1</sup>, and P. Molle<sup>1</sup>.

<sup>1</sup> Irstea, Freshwater Systems, Ecology and Pollutions Research Unit, 5 rue de la Doua, BP 32108, 69616 Villeurbanne, France

\* Presenting Author: [vivien.dubois@irstea.fr](mailto:vivien.dubois@irstea.fr)

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## INTRODUCTION

Onsite sanitation systems in Europe are evaluated through a EU labeled procedure done on a platform test under a specific schedule of loads (EN 12566). Nevertheless this test procedure conditions does not represent the real conditions of treatment systems in term of wastewater characteristics and loads. On another angle, in France, systems implemented for capacities above 20 p.e. do not need EU labeled procedure but have to comply with performances requirements. For constructed wetlands, it leads to a situation where design for 21 p.e. can be more compact than for 15 p.e.. Some companies have fulfil EU labeled procedure for one stage vertical flow constructed design between 1.2 and 2 m<sup>2</sup> per habitant to implement more compact system. This study aims at evaluating, under real conditions the behaviour of a one stage unsaturated/saturated vertical flow constructed wetlands (as designed for small communities, Pringent et al., 2013; Silveira et al., 2015) and fed by raw wastewater (no septic tank). The objectives were to evaluate performances, robustness and resilience of the system when facing load variations.

## MATERIAL AND METHODS

The monitoring have been conducted on a unsaturated/saturated vertical flow constructed wetland treating the wastewater from 6 habitants family in the south of France (Crest, Drôme department). The system consists in:

- A pumping station receiving all wastewaters from the house (no screening) and delivering batches to the treatment system. The batch feeding flow is of 3 m<sup>3</sup>/h for an average batch volume of 80 liters.
- A unsaturated/saturated vertical flow constructed wetlands divided in two filters in parallel to implement feeding and resting periods (one week/one week). The filters comprises a 70 cm of 2/6 mm crushed and washed gravel (unsaturated layer), an aeration pipe and a saturation layer composed of pea gravel (20/40 mm). The saturation layer has been tested between 22 and 40 cm of depth. Each filter has a surface of 7 m<sup>2</sup>.

Treated wastewaters are infiltrated into the ground in winter and reused for brush irrigation the rest of the year.

The monitoring, over one year and half, started after 3 years of operation and consisted in:

- Counting the number of people present in the house for the night, the lunch and the dinner, every days.
- Measuring the daily flow by a pressure probe (STS) in the pumping station measuring on a one minute time step
- Performing 24 h flow proportional samples at the inlet/outlet of the system to analyse global parameters (COD, dissolved COD, TOC, DOC, TSS, BOD<sub>5</sub>, KN, N-NH<sub>4</sub>, N-NO<sub>2</sub>, N-NO<sub>3</sub>, P-PO<sub>4</sub>, TP). 31 campaigns have been done in different seasons.
- For some campaigns outlet online measurement of N-NO<sub>3</sub>/N-NH<sub>4</sub> have been done (WTW Varion).

## RESULTS AND DISCUSSION

### Characterization of habitant pollutant production

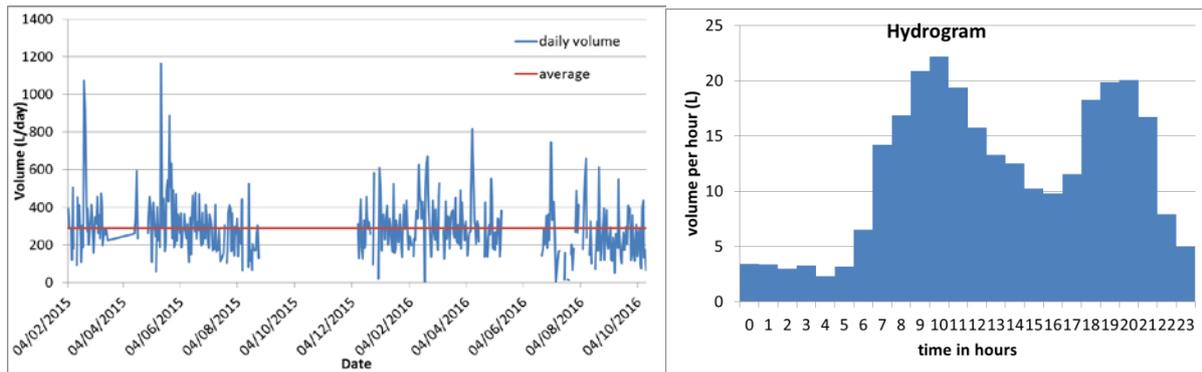
Wastewater characteristics observed on the site reveals that concentrations are much higher than the one usually used in EU labeled tests (see Table 1).

**Table 1: Wastewater characteristics**

	Volume (L)	COD (mg/l)	dCOD (mg/l)	TSS (mg/l)	BOD <sub>5</sub> (mg/l)	KN (mg/l)	N-NH <sub>4</sub> (mg/l)	TP (mg/l)
average	521	1853	467	1032	767	209	152	29
median	347	1780	470	1065	784	207	148	29
min	67 (150)*	358 (300)*	53	213 (200)*	530 (150)*	29 (25)*	16.8 (22)*	5.5 (5)*
max	4397 (150)*	2750 (1000)*	708	1590 (700)*	1100 (500)*	330 (100)*	252 (80)*	43.6 (20)*

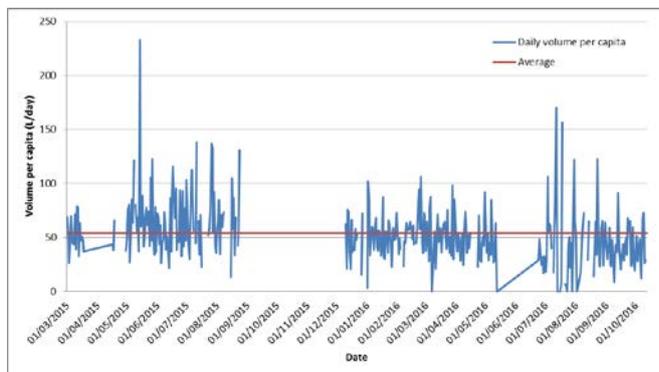
(XX)\*: Reference values for EU labeled tests

The hydraulic load received varies significantly with some huge loads (maximum of 4.4 m<sup>3</sup>/d representing a hydraulic load on the filter in operation of 63 cm/d) for very special events. Excepting the specials events, the daily volume production and classical variation within a day can be seen on Figure 1.



**Figure 1.** daily hydraulic load (left) and average hydraulic load distribution during the day (right)

The average daily flow volume is of 290 liters per day. When comparing to human presence in the house each day, the generated daily volume per capita is of 54 liters in average (Figure 2).



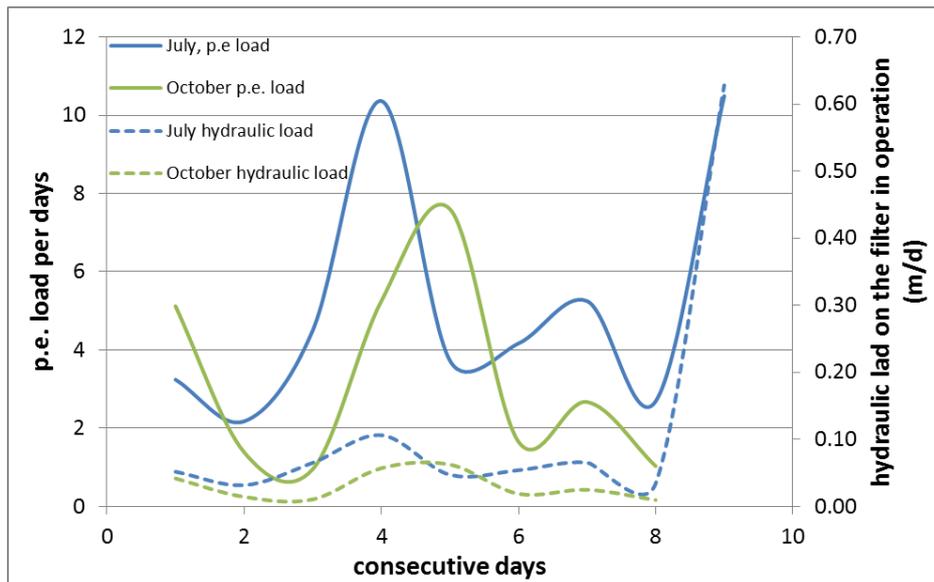
**Figure 2.** daily generated volume per capita

The measurements allow quantifying volume variations, which can double quite often even, for special events, be multiplied by 3 or more. The unique special event, with more than ten times the average hydraulic load, corresponds to a forgotten open tap associated with more people in the house. If this event can be seen as an accident and unusual situation it is important to evaluate if such an event can be accepted by the system or damage its functioning.

### Treatment performances

Based on a 60g of BOD<sub>5</sub>/p.e./d and 150 g of COD/p.e./d the system received an corresponding organic load of about 4 p.e. (one habitant is not equal to a people equivalent) with a maximum monitored load of 10.5 p.e. Even in term of organic load, variations are important and sudden.

Inlet outlet concentrations for all measured parameters are presented in Table 2. Whatever inlet concentration variations, outlet concentrations remain always low for carbon pollutant parameters, solids and nitrification. It allows realize the stability of the system regarding inlet hydraulic and organic load variations. Indeed, Figure 3 presents the organic and hydraulic load variations over consecutive days for two seasons. If hydraulic load remains globally low compared to what such system can accept (Molle et al., 2006), except for the exceptional event, the organic load vary a lot which could affect biological stability and efficiency.



**Figure 3** : organic and hydraulic loads variations over consecutive monitoring days for two seasons

**Table 2 : Inlet – outlet concentrations during 24 h proportional flow composite samples campaigns**

	TSS (mg/l)		COD (mg/l)		CODd (mg/l)		BOD <sub>5</sub> (mg/l)		TOC (mg/l)		DOC (mg/l)		KN (mg/l)		N-NH <sub>4</sub> (mg/l)		N-NO <sub>2</sub> (mg/l)		N-NO <sub>3</sub> (mg/l)		TP (mg/l)		P-PO <sub>4</sub> (mg/l)	
	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out	in	out
average	1032	10	1853	62	467	49	767	7	578	25	163	19	209	12	152	7.8	0.08	0.19	1.4	69	29	17	10	14
Median	1065	9	1780	57	470	49	784	7	588	24	157	19	207	9	148	5.4	0.04	0.16	0.5	62	29	20	9	15
Min	213	2	358	23	53	20	530	3	435	19	116	14	29	3	17	0.3	0.02	0.02	0.5	15	6	8	2	7
Max	1590	22	2750	100	708	82	1100	16	762	30	240	24	330	29	252	22.5	0.51	0.53	5.1	148	44	23	20	21
Nb of value	30	30	31	31	31	31	13	13	17	17	13	13	31	22	31	31	31	31	31	31	28	28	28	28

Despite these high load variations, performances removal stay stable as it can be seen on Figure 3. It appears that removal performances are extremely stables with, on average, more than 98 %, 99 %, 94 % and 97 % for TSS, BOD<sub>5</sub>, COD and KN respectively. Even if the hydraulic load is usually low, organic load can reach values similar to nominal design of French vertical flow constructed wetlands (Molle et al., 2005).

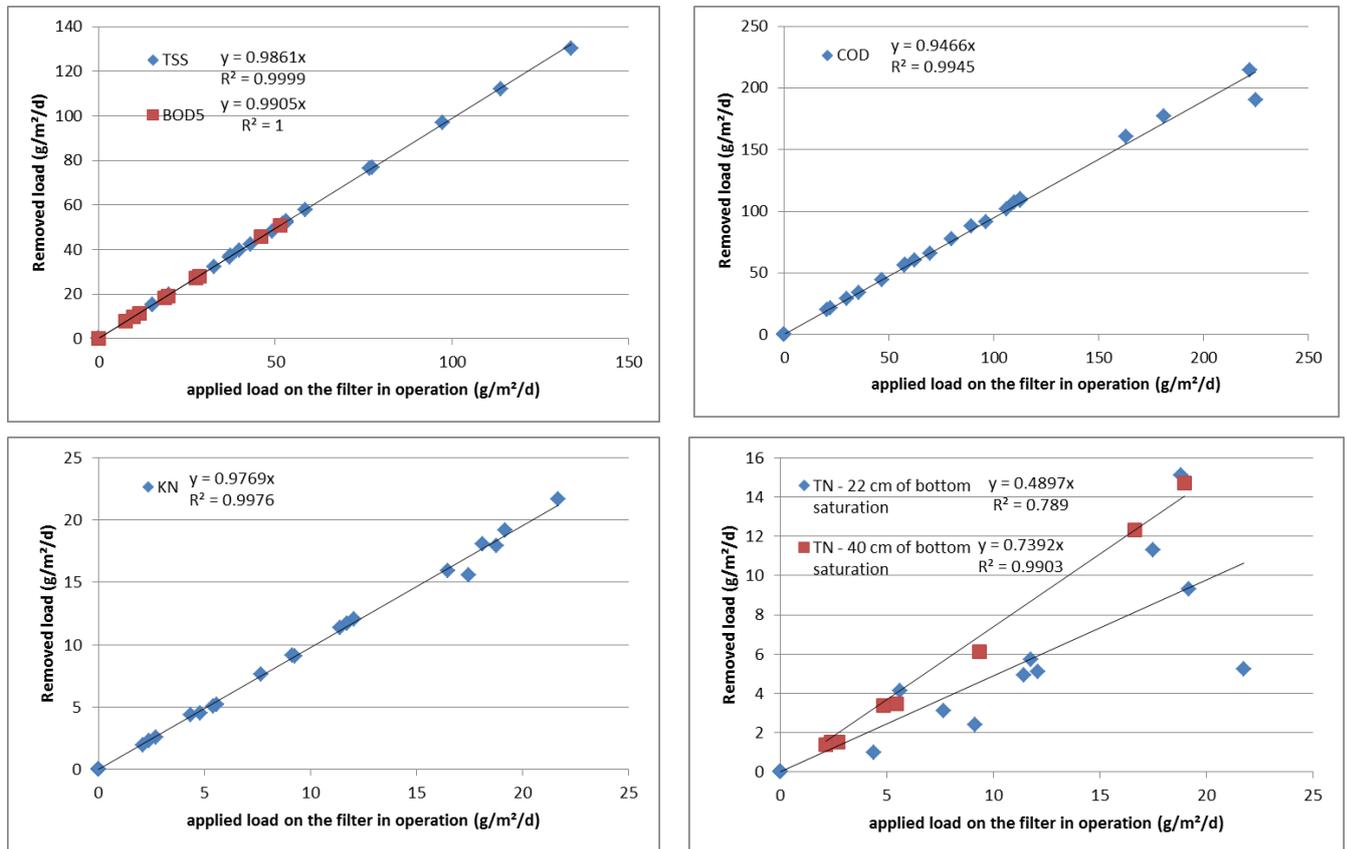


Figure 4: applied and treated loads on the filter in operation.

TN removal still not complete and no clear correlation can be done according to season. It appears that increasing the depth of the bottom saturation from 22 cm to 40 cm allowed to improve total nitrogen removal (Figure 4). With 22 cm of saturation TN removal is about 45 % and not stable, while with 40 cm total nitrogen removal reached around 70 %. It is likely not possible, with such a unsaturated layer (70 cm), to reach better TN performances as the outlet available carbon is very low. Average and median outlet COD concentrations were of 68 and 69 mgCOD/l when implementing a 22 cm saturation and of 46 and 45 mgCOD/l when implementing a 40 cm saturation depth. It is likely that those last values are close to the non-biodegradable part of COD.

Phosphorus is not correctly treated in the filter as no specific materials are implemented. Only 40 % on average is removed and correspond mainly to the particulate form of P that is filtrated by the system.

Feeding the system with raw wastewater should lead to an organic deposit accumulation on the filter's surface (Molle et al., 2005). Due to the low load applied, and despite that reeds are cut but not removed from the filter, it is not possible to measure a deposit layer depth after 5 years of operation. Main of the deposit is mineralized, which eases the sludge management and confirms the interest in feeding the system with raw wastewater.

## CONCLUSIONS

The real scale monitoring over one year and half of an onsite constructed wetlands system allows to draw some global information.

In terms of wastewater production and variation on a single house:

- Wastewater concentration characteristics are much higher than the one used in EU labeled tests. Onsite system needs to face higher concentrations.
- There is not a proportional relation between the number of people in the house and the amount of emitted water. The emitted volume per person is on average three times lower than the reference value used in the EU labeled tests but can vary between 4 and 304 liters.

This could question the relevance of the EU test and the difference of treatment systems behavior between labelled test and real life.

- Organic load variation can vary up to a ten factor from one day to another one and requires treatment system to be robust and resilient to un-expected events.

In terms of performances of the unsaturated/saturated vertical flow constructed wetlands tested, we noted that the system stays very stable whatever the variations observed during the monitoring. Removal performances are very high and outlet concentrations low and stable despite inlet variations. If performances are high for solids, carbon removal and nitrification, TN removal is impacted by the depth of the saturation level. The designed implemented seems not able to go higher than 70 % of TN removal as it doesn't still carbon source for denitrification at the outlet. To reach higher level, design should be modified, balancing nitrification performances and TN removal.

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