Comparison of vertical flow treatment wetlands to other treatment technologies in real operating conditions under tropical climate

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Abstract: The main treatment technologies implemented in the French Overseas Territories are compared based on the analysis of self-monitoring database built for this study. Activated sludge is the most implemented but least reliable technology, due to sludge leakages noticeable on 10% of the campaigns. Algae growth limits facultative ponds performances. Settling troubles have been identified on rotative biological contactor. Vertical flow treatment wetlands show the best performances. Coefficient Of Reliability use and comparison with data from Brazil confirm those results.

Keywords: Activated Sludge / Domestic wastewater / technology Reliability

Session use of wetland

Introduction

Wastewater management in the French Overseas Territories (FOT) is lagging behind France mainland and both French and European regulations. To optimize public investment, suitable technologies to tropical conditions have to be implemented. It requires feedbacks on wastewater treatment plant (WWTP) behaviours in such operating conditions. Consequently a study has been conducted in the five FOT (Martinique, Guadeloupe, Mayotte, La Réunion and French Guyana) to compare treatments technologies performances. The study focused on systems capacities between 20 and 2 000 people equivalent (p.e.).

Material and Methods

A data-base of 24 h flow composite samples has been built with data gathered from 2 different sources:

• WWTP self-monitoring, performed according to French regulation (frequency, parameters). Those data are available from the FOT since 2012.

• Local water authorities, which had occasionally carried out studies on specific technologies, local area, or precise capacity.

A validation step, through raw wastewater data was performed. It aimed at removing inconsistent data or outliers. They have been identified statistically as presented by Morvannou et al. (2015) with PCA and Chauvenet's criterion tests, on both inlet pollutants concentrations and ratios between them, such as COD/BOD5, TKN/COD, TSS/COD and NH4-N/TKN. With a small amount of data removed (from 0.59% for COD to 3.29% for NH4), the database gained consistency (reduction of standard deviation: from 92.5% for COD to 13.9% for NH4).

In order to confirm results from self-monitoring, 4 campaigns of 24 h flow composite samples have been performed on 8 treatment systems in accordance with the database composition. Those

plants are located in French Guyana and Martinique Island. Analyses were done by local accredited laboratory on the main pollutants parameters (COD, BOD5, TSS, TKN, N-NH4, N-NO2, N-NO3, TP).

A comparison of the main treatment systems reliability regarding different discharge standards was performed, based on the Coefficient Of Reliability (COR) methodology developed by Niku et al., (1979). COR was calculated for each treatment plant of the database containing more than 5 sampling campaigns data available. It was used to calculate a theoretical design concentration to achieve, in order to meet the standard for developing countries adopted by Oliveira & Von Sperling (2008). Then, observed mean concentrations are compared with those obtained with the COR. Results of the 4 treatment technologies are compared with those presented by Oliveira & Von Sperling (2008) in Brazil.

Results and Conclusions

About 900 WWTP under 2 000 p.e. have been identified in the FOT (Figure 1). Amongst them, a large part of the treatments systems remains unknown (42%) or belongs to on-site sanitation systems (22%). As no data were available for those categories (no obligation < 200 p.e.), they have not been included in the study. Activated sludge is the main technology implemented in the FOT.

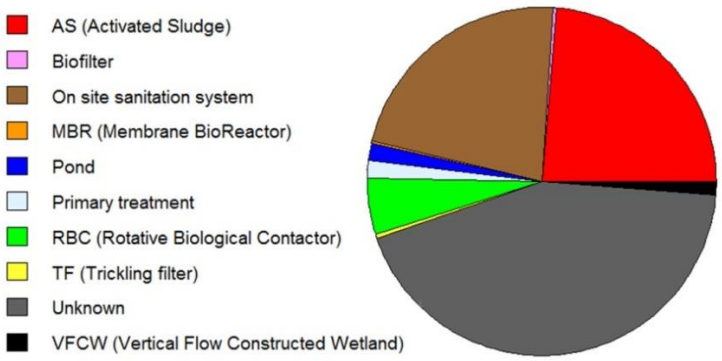

Figure 1 Repartition of the different treatment technology in the FOT (900 WWTP identified between 20 and 2 000 p.e.).

The database with consistent information counts 267 WWTP, and about 1 200 sampling campaigns. Four treatments systems (biofilters, membrane bioreactors, primary treatment, trickling filters) were removed because the corresponding number of units was to low (<10). Finally, four technologies (activated sludge, pond, rotating biological contactor, single stage vertical flow constructed wetland) representing 213 plants and 962 sampling campaigns were usable for performances assessments.

Performances are presented with cumulative percentages of removal efficiency (Figure 4). They are discussed regarding the French minimal regulation objectives (removal rates: 60/60/50% for BOD5/COD/TSS or outlet concentrations below 35/200 mg/L for BOD5/COD).

AS is the most implemented technology, but it shows the weakest performances: 18 % of the campaigns are below the minimal removal regulatory objectives for TSS and COD. This is due to sludge leakage, as shown by null (or negative) removal rates for TSS in about 10% of the sampling campaigns.

Facultative Ponds (FP) present null removal rate for COD and TSS for about 10% of the campaigns due to algae production (as suggested by good nitrification of dissolved NH4 and low removal of NTK) reinforced by the low load applied (outlet concentrations are good).

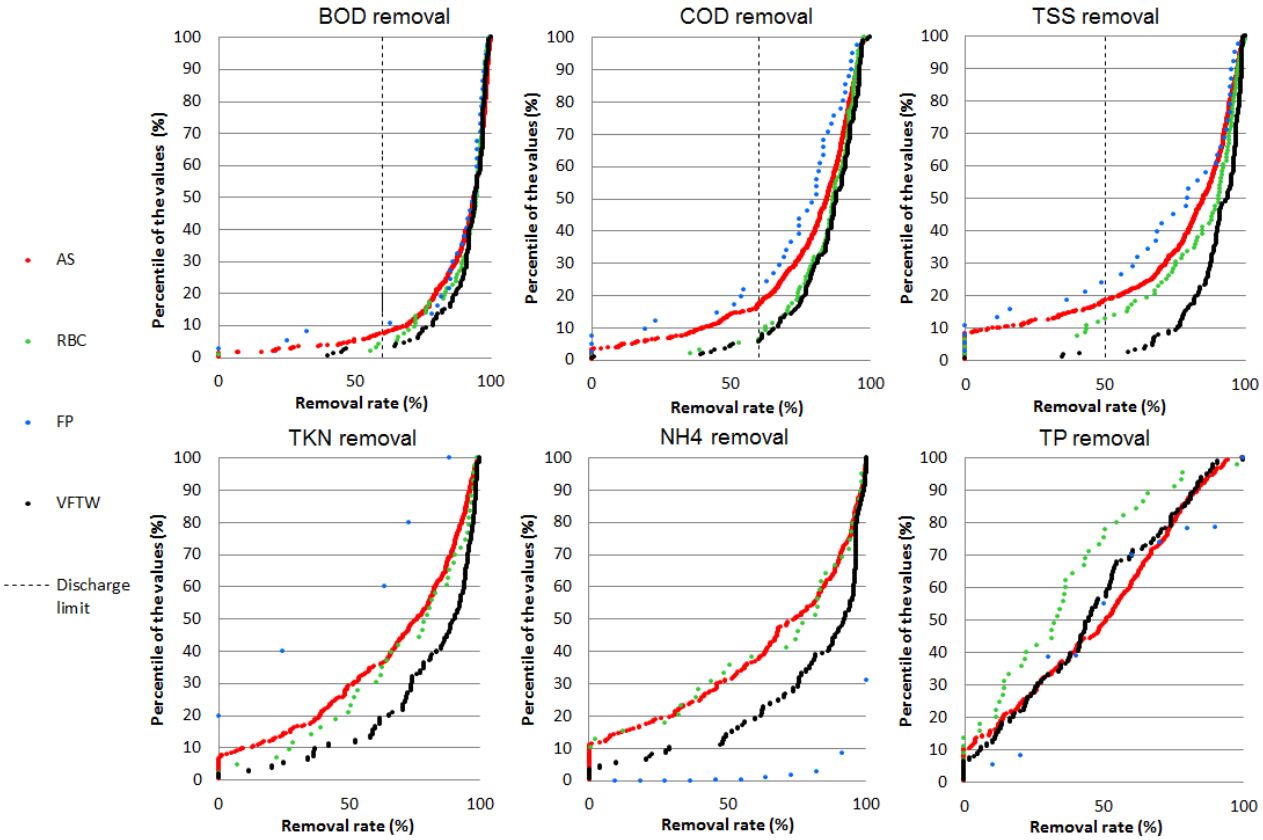

Figure 2 Removal efficiency of the treatments technologies for the main pollutants.

RBC performances are much better (close to 95%) for carbon loads, but with 13% of samplings below the regulation objectives for TSS, sludge leakages may occur in the settling stage. The clarifiers are effectively often a sensitive step regarding storm events and sludge management.

VFTW show the best performances by fulfilling all the objectives at a frequency of 90 to 95%.

The monitoring performed during this study on 8 different plants show that the database seems to overestimate most of the treatment technologies performances (Table 1). This monitoring focused on small systems, below 1 000 p.e., for which self-monitoring has a lower frequency. This leads to a relative under representation in the database and may explain part of the differences. Nevertheless, the diagnostics based on the database exploitation are confirmed (sludge leakage, settling troubles and algae growth). All of the systems were in operation, but most of them suffer from limited maintenance (2 visits per months).

Table 1 Compliance percentage with French minimal discharge limit by treatment technologies. (n) for number of 24h sampling campaigns.

	BOD		**COD**		**TSS**	**Total**
	Outlet concentrations	Removal efficiency	Outlet concentrations	Removal efficiency	Removal efficiency	
4 AS (16)	73%	100%	73%	73%	73%	64%
2 RBC (8)	37%	100%	50%	75%	62%	37%
2 FP (8)	75%	100%	87%	37%	27%	37%

Comparison of the 4 treatment technologies based on the COR confirm previous observations. AS is the least reliable technology: comparison of design and observed mean concentrations (table 2), shows that AS technology is unable guarantee the discharge standard. RBC and FP are limited by TSS (and BOD for RBC). VFTW could achieve all the required discharge level, except for TKN. VFCW in the FOT has mainly a single stage; full nitrification is out of range in this configuration.

Table 2 Design (DC) and observed (*OC*) mean concentrations for the 4 technologies studied in the FOT and comparison with data from Brazil (Oliveira & Von Sperling, 2008). ST: Septic Tank; AF: anaerobic filter; AP: anaerobic pond; UASB: upflow anaerobic sludge blanket; POST: post-treatment. The expected discharge standard is DBO = 60 mg/L; COD = 200 mg/L; TSS = 60 mg/L; TN = 20 mg/L ; TKN = 20 mg/L.

		BOD (mg/L)		COD (mg/L)		TSS (mg/L)		TN (mg/L)		TKN (mg/L)	
		DC	*OC*	DC	*OC*	DC	*OC*	DC	*OC*	DC	*OC*
FOT	AS	25	*37*	100	*129*	25	*64*			11	*22*
	RBC	26	*41*	102	*101*	24	*47*			12	*17*
	FP	30	*12*	111	*85*	25	*41*			-	-
	CW	27	*15*	112	*68*	24	*25*			11	*13*
Brazil	ST+AF	29	*292*	104	*730*	29	*165*	12	*61*		
	FP	30	*136*	127	*525*	31	*216*	11	*38*		
	AP+FP	98	*89*	127	*309*	34	*153*	12	*45*		
	AS	24	*35*	85	*92*	23	*57*	10	*22*		
	UASB	30	*98*	107	*251*	26	*85*	15	*48*		
	USAB+POST	27	*42*	98	*141*	26	*51*	-	-		

Data from brazil (Oliveira & Von Sperling, 2008) allow to widen the comparison to other treatment technologies. AS and FP are common to the 2 studies. Regarding AS, both design and observed mean concentrations are very close suggesting that data of the 2 studies are comparable. FP shows larger differences, which can be explain by the low load and the dilution of the influent in the FOT (average 40% of COD nominal rate for 90% of hydraulic load). In terms of reliability, UASB+POST is close to RBC (except for COD). Other treatments technologies present bad correlation between design and observed concentrations. Amongst the technologies evaluated, VFTW seems to be the most reliable for tropical conditions.

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