How sludge management can affect the performance of full-scale UASB-based sewage treatment plants

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Highlights:

- Proper sludge management strategies improve the performance of full-scale UASB-based sewage treatment plants.
- Aerobic sludge can be safely sent for thickening and digestion in the UASB reactor when a consistent slugde management routine is implemented.

Keywords: municipal wastewater; trickling filter; excess sludge.

INTRODUCTION

Upflow anaerobic sludge blanket (UASB) reactors for mainstream sewage treatment in warm climate regions has expanded significantly and is considered a consolidated technology (Chernicharo & Bressani-Ribeiro, 2019). Although it is widely known that a key aspect for the good performance of the technology is the proper management of excess sludge, it has been neglected in most of the sewage treatment plants (STP) in Brazil, causing several problems for the treatment system.

The proper management of the sludge presupposes that the maximum sludge storage capacity inside the UASB reactor is not exceeded, which is dictated mainly by the volumes of its digestion and settler compartment. If the sludge storage capacity is exceeded, excessive solids washout and deterioration of the effluent quality may occur, in addition to other related problems (e.g., overload of the post-treatment unit) (Chernicharo & Bressani Ribeiro, 2019). Therefore, it is mandatory that the excess sludge is removed periodically and according to the capacity of the dewatering system used. The aim of this paper is to show how sludge management can impact the performance of a small full-scale UASB-based sewage treatment plant.

METHODOLOGY

The flowsheet of the STP comprises preliminary treatment units, UASB reactors followed by a trickling filter (TF) coupled with a secondary settler, as shown in Figure 1. The excess aerobic sludge withdrawn from the secondary settler is returned to the UASB reactors for thickening and digestion. The excess sludge withdrawn from the UASB reactors is routed to sludge drying beds and, subsequently, disposed of in a landfill. The main characteristics of the UASB + TF system are presented in Table 1.

Although the plant has been in operation since 2015, a proper protocol for sludge management was implemented only in 2021. In the previous years (2015-2020), the plant has experienced different operational conditions, as characterized in the phases shown in Table 2.

RESULTS AND CONCLUSIONS

Box plot graphs of the BOD, COD and TSS results obtained during the four operational phases of the plant (111 months in total) are depicted in Figure 2. Although the positive impact of proper sludge management cannot be observed directly, because the effluent concentrations of the UASB reactor are not shown, the following general comments can be made regarding the overall performance of the plant:

- Although the plant had been operated under low average flowrate (6.1 $L.s^{-1}$) and extremely high average HRT (around 30 hours in the UASB reactor) during phase 1, the final effluent quality was about the same of what was observed for phase 2, when the plant was operated at double average flowrate (12.2 $L.s^{-1}$) and half of the HRT of phase 1.
- Even better results were observed during phases 3 and 4, when the plant was also operated at high flowrates (11.0 and 12.3 $L.s^{-1}$, respectively), but with a fully developed and implemented sludge management routine (see footnote on Table 2).
- The excellent results obtained during phase 4 can be highlighted, when the plant was operated with a single UASB reactor (at the design parameters), proving the importance of adequate sludge management practices under higher flowrates. This allowed the production of a very high-quality final effluent in terms of median BOD (28 $mg.L^{-1}$), COD (109 $mg.L^{-1}$), and TSS (21 $mg.L^{-1}$).

The positive impact of the adopted sludge management routines (see footnote on Table 2) is clearly observed in Figure 3, particularly when considering the contents of settleable solids (SetS) in the effluent of the UASB reactor. SetS are extremely variable and present a high average value (3.0 $mL.L^{-1}$) in phase 1, still variable but with a lower average value (0.9 $mL.L^{-1}$) in phase 2, and much more stable in phases 3 and 4. In phase 4, the median value was 0.6 $mL.L^{-1}$ and 90% of the results stayed below 1.1 $mL.L^{-1}$.

Overall, this study confirms the importance of implementing adequate sludge management strategies to improve the performance of full scale UASB-based sewage treatment plants.

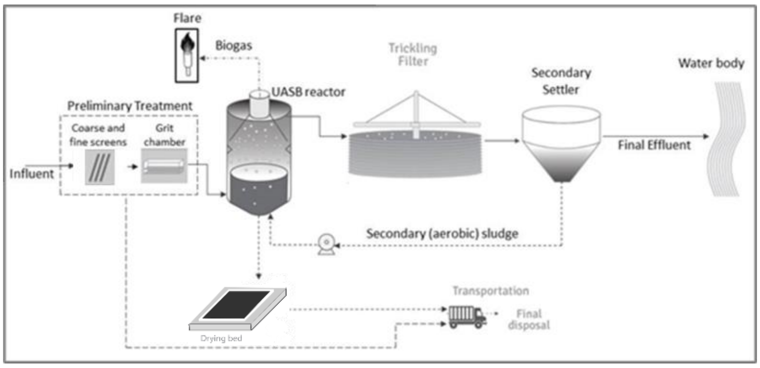

Figure 1 – Flowsheet of the sewage treatment plant.

Table 1 – Main design parameters of the UASB + TF system.

Parameters	UASB reactors	Trickling filter	Secondary settler
Population equivalent (PE)		11,560	
Flow rate (L.s-1)		23.1	
Number of units	2	1	1
Dimensions (m)	12.4 x 5.9	D = 14.0	D = 12.0
Useful depth (m)	4.50	2.20	3.0

Table 2 – Characterization of the operational phases.

Parameter	Unit	UASB reactors				Trickling filter				Secondary settler			
		Phase 1	Phase 2	Phase 3	Phase 4	Phase 1	Phase 2	Phase 3	Phase 4	Phase 1	Phase 2	Phase 3	Phase 4
Duration	month	1-32	33-75	76-105	106-112	1-32	33-75	76-105	106-112	1-32	33-75	76-105	106-112
Average flow	L/s	6.1	12.2	11.0	12.3	6.1	12.2	11.0	12.3	6.1	12.2	11.0	12.3
Units in operation	un.	02	02	02	01	01	01	01	01	01	01	01	01
HRT	h	30.1	15.0	16.6	7.4	-	-	-	-	15.5	7.7	8.6	7.7
SLR	$m^3.m^{-2}.h^{-1}$	0.15	0.30	0.27	0.61	0.14	0.29	0.26	0.29	0.19	0.39	0.35	0.39
Sludge management practices implemented? *		NO	NO	YES	YES	NO	NO	YES	YES	NO	NO	YES	YES

HRT: hydraulic retention time; SLR: surface loading rate

(*) Sludge management practices consisted of: i) more accurate estimation of the amount of excess sludge to be discharged from reactor bottom and reactor middle height; ii) preservation of the more concentrated sludge (reactor bottom); iii) establishment of a proper routine for returning the aerobic sludge (from the secondary settler) for thickening and digestion in the UASB reactor. *Details of these practices will be addressed in the full paper*.

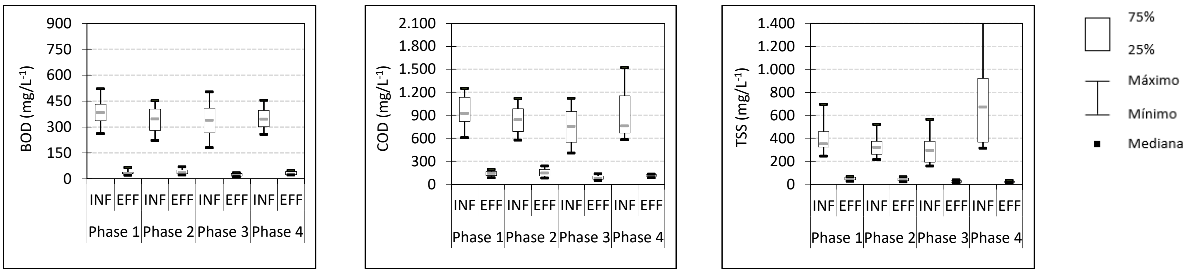

Figure 2 – Box plot of influent (INF) and effluent (EFF) concentrations during the operational phases: a) BOD; b) COD; (c) TSS.

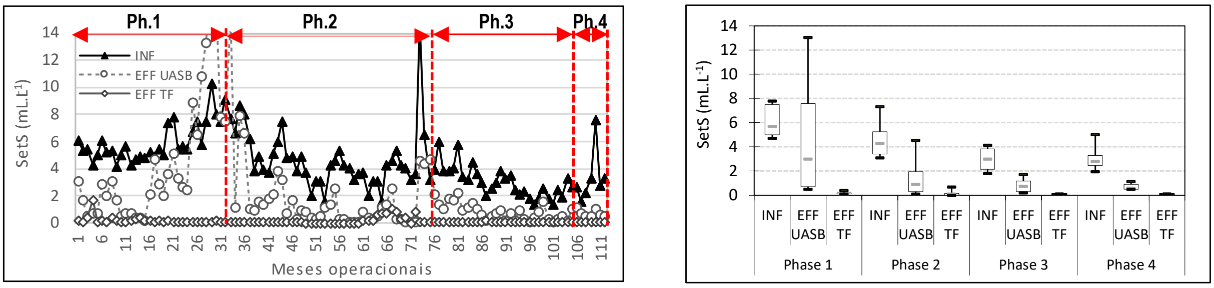

Figure 3 – Influent (INF), effluent of UASB reactor (EFF UASB), and effluent of TF - final effluent (EFF TF) concentrations of settleable solids (SetS) during the operational phases: a) historical series; b) box plot.

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