Performance of a system with full- and pilot-scale sludge drying reed bed units treating septic tank sludge in Brazil

Luisa Fernanda Calderón-Vallejo, Cynthia Franco Andrade, Elias Sete Manjate, Carlos Arturo Madera-Parra and Marcos von Sperling

ABSTRACT

This study investigated the performance of sludge drying reed beds (SDRB) at full- and pilot-scale treating sludge from septic tanks in the city of Belo Horizonte, Brazil. The treatment units, planted with *Cynodon* spp., were based on an adaptation of the first-stage of the French vertical-flow constructed wetland, originally developed for treating sewage. Two different operational phases were investigated; in the first one, the full-scale unit was used together with six pilot-scale columns in order to test different feeding strategies. For the second phase, only the full-scale unit was used, including a recirculation of the filtered effluent (percolate) to one of the units of the French vertical wetland. Sludge application was done once a week emptying a full truck, during 25 weeks. The sludge was predominantly diluted, leading to low solids loading rates (median values of 18 kgTS m^{-2} $year^{-1}$). Chemical oxygen demand removal efficiency in the full-scale unit was reasonable (median of 71%), but the total solids removal was only moderate (median of 44%) in the full-scale unit without recirculation. Recirculation did not bring substantial improvements in the overall performance. The other loading conditions implemented in the pilot columns also did not show statistically different performances.

Key words | *Cynodon* spp., French vertical flow constructed wetland, planted drying beds, sludge treatment wetlands, septage

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INTRODUCTION

A major challenge in the implementation of sustainable and low-cost sanitation is related to the sludge derived from septic tanks (ST), which are an on-site sanitation solution employed in many countries in the world. The disposal of untreated faecal sludge into the environment causes serious degradation problems and severe public health risks. The sludge (septage) must be treated and adequately disposed, due to the high concentrations of non-stabilized organic matter and pathogenic organisms (Suntti *et al.* 2011), and there are several treatment options and technologies (Strande *et al.* 2014).

ST are one of the most often employed technologies for the treatment of domestic sewage in Brazil and in several developing countries. According to Furtado (2012), ST serve about a quarter of the Brazilian population. There is an estimated production value of about 80,000 m^3 d^{-1} of wet septic sludge in Brazil, with a potential generation of approximately 7 million m^3 $year^{-1}$ of digested septic sludge. Only few Brazilian municipalities have adequate systems for collection, transportation and disposal of the septage. In some places of the country, it is discharged into the sewerage system or into wastewater treatment plants; consequently the treatment is held combined with the sewage. Taking into account all these problems, simple and natural technologies like constructed wetlands could be an excellent alternative for the treatment of the sludge from ST, contributing to the improvement of the water resources and the environment in general.

Although vertical-flow constructed wetlands (VFCW) have been employed in wastewater treatment for several years, systems for dewatering and stabilizing the sludge are far less numerous (Stefanakis *et al.* 2011). Sludge drying reed beds (SDRB) for sludge treatment are also known as planted drying beds or sludge treatment wetlands (STW) all over the world. SDRB is a technology that has been used since the late 1980s, nonetheless the number

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of plants in operation is still very low in comparison with conventional technologies (Uggetti *et al.* 2010). For sludge treatment, SDRB are recommended, due to the large concentration of solids in this type of influent (Koottatep *et al.* 2001). In general, SDRB allow the accumulation of the sludge with a useful lifetime of several years and a low area requirement, reducing handling costs, transportation and disposal of sludge (Koottatep *et al.* 2001; Uggetti *et al.* 2010; Cui *et al.* 2012).

Plants such as *Typha augustifolia* (Koottatep *et al.* 2004), *Phragmites australis* (Troesch *et al.* 2009) and *Zizaniopsis bonariensis* (Suntti *et al.* 2011) have been used for sludge treatment. In contrast, the study of *Cynodon* has been very limited in the international context, with few reported studies (Vymazal 2013). For the case of Brazil, this plant has been studied in constructed wetlands for swine wastewater (Matos *et al.* 2009; Fia *et al.* 2011), dairy wastewater (Matos *et al.* 2010a; b) and domestic sewage (Cota 2011; Lana *et al.* 2013; Manjate *et al.* 2014), with good results. The evaluation of *Cynodon* for septage treatment was not found in the literature; therefore, this research was aimed at partially filling this gap.

Another motivation of the research was to study the utilization of a vertical-flow wetland unit of the French type, originally conceived for treating sewage, under the different operating conditions associated with septic tank sludge.

The objective of this research was to assess the performance of a SDRB planted with *Cynodon* spp. at full and pilot scales for solids and organic matter removal from septic tank sludge under different hydraulic and solids loading rates (HLR and SLR), with and without recirculation of the percolated effluent.

METHODS

Full-scale unit

The research was conducted at the Center for Research and Training in Sanitation (CePTS), of the Federal University of Minas Gerais (UFMG) and the Water and Sanitation Company of Minas Gerais (COPASA), located at the Arrudas wastewater treatment plant in Belo Horizonte, Brazil (latitude 19°53′ S). Belo Horizonte is located in Cfa or Cwa humid subtropical climate according to Köppen classification, with a mean annual air temperature of 22.1 °C and mean annual rainfall of 1,540 mm $year^{-1}$.

In CePTS, there is a system composed of three vertical-flow units, comprising the first stage of a typical French system, built for sewage treatment according to the specifications and recommendations of the French Institution Irstea (formerly Cemagref). Each of the three full-scale planted beds (FSW) have a length of 9.3 m, width of 3.1 m, area of 29.1 m^2, a bed with 0.7 m of gravel filter media height (fine, medium and coarse gravel – see Figure 1), porosity of 40%, and are planted with *Cynodon* spp. (Cota 2011; Lana *et al.* 2013). The particle sizes differ slightly from the design features suggested in Molle *et al.* (2005) for the French system due to the commercial availability of this material in Brazil (Cota 2011). Sand at the top layer, which is frequently used in many sludge reed drying beds to enhance filtration capacity, was not applied here, because the idea was to employ one unit of the first stage of the French vertical wetland, without altering its basic physical specifications. The units have been in operation since 2009, receiving sewage. However, for this research, from September 2013, one unit (FSW#1) stopped receiving

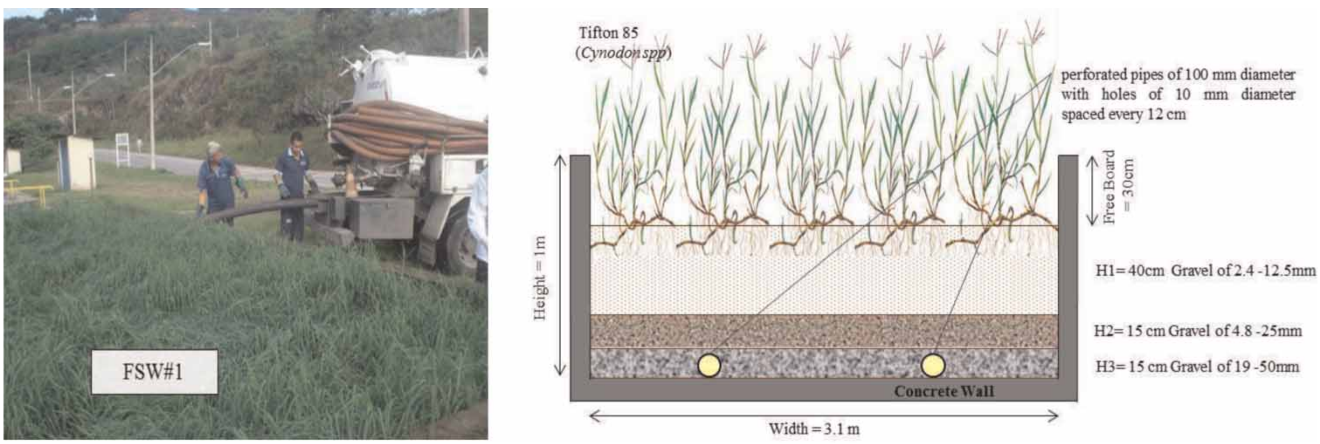

Figure 1 | Full-scale unit receiving sludge and schematic cross section of each unit.

sewage and was then dedicated only to septic tank sludge, while the two other units continued to receive wastewater. Other characteristics of the system and its configuration can be seen in Figure 1.

When septic tank sludge application started in FSW#1, the unit was not renewed and the gravel was not removed nor cleaned, and the unit was simply switched to operating with sludge. Regarding organic matter conditions in the gravel, studies carried out by Lana *et al.* (2013) showed that before the modification a higher biomass accumulation occurred in the first 0.40 m of the bed layer. Results also suggested that there was no evidence of clogging.

The study was divided into two different phases. Phase 1 included septic tank sludge application in both systems, the full-scale system (FSS) and the pilot-scale systems (PSS). Prior to Phase 1, construction and commissioning of six pilot columns was executed during an approximate period of 2 months. In addition, Phase 1 was aimed at comparing different operational conditions between FSS and PSS during a period of 10 weeks, from January up to March 2014. The age of the full- and pilot-scale units was different, since the latter were built in November 2013 and the full-scale unit was operational for 4 years, with a better establishment of the bed and roots. The full-scale and pilot units were fed with sludge from ST once a week. The remainder of the week (6 days) was used as a resting period to allow digestion and dewatering of the accumulated sludge on the top of the units. Phase 2 comprised the performance evaluation of the FSS during a longer period, from January up to July 2014. Field data were obtained during 9 and 25 weeks for the first and second stages, respectively. Sludge was also applied once a week during this period.

The remaining two units of the first stage of the French system (FSW#2 and FSW#3) continued operating in alternating mode, with each unit receiving wastewater in hourly batches over 1 week, followed by a rest period of 1 week. These two units were also used for receiving the liquid effluent (percolate) from the sludge unit (FSW#1), in order to allow a further improvement in its quality. The application of the percolate was done immediately after its generation, and was directed to the unit (FSW#2 or FSW#3) that was in the rest period at each week.

Pilot-scale units

While FSW#1 represented septic tank sludge application for real conditions, the six pilot beds (PW1, PW2, PW3, PW4, PW5 and PW6) allowed investigation of different operational conditions with the same sludge. The columns were made of PVC tubes of 146 mm of internal diameter and an area of 0.0165 m^2. Both systems, FSS and PSS had the same configuration regarding the filter media height and its composition, as well as the type of plant (*Cynodon* spp.). One plant from the full-scale unit was sown in PW2, PW3, PW4, PW5 and PW6, respectively, and was allowed to grow and propagate. The operational conditions for the pilot-scale units were as follows:

- PW1: same HLR as the full-scale unit, but unplanted;
- PW2: same HLR as the full-scale unit;
- PW3: half the HLR of the full-scale unit;
- PW4: double the HLR of the full-scale unit;
- PW5: same as unit PW2, but with sludge recirculation onto itself;
- PW6: same as unit PW2, but with worms.

The only unplanted unit was PW1. For PW6, the amount of common earthworms (*Lumbricus terrestris*) added was calculated as recommended by Munroe (2007), between 5 and 10 kg m^{-2}, resulting in a total mass of added worms of 90 g.

Septic tank sludge application

Once a week, the first sludge truck to arrive at the treatment plant was used to feed the beds. All the volume in the truck was discharged into the full-scale unit, and a small portion of it was discharged into the pilot units. Sludge application for the pilot units was done using buckets of 12 L of samples collected from the starting, middle and ending time of the volume discharged from the truck, followed by further mixing prior to the application. Since different trucks were used, the sludge had different origins, likewise very different characteristics in its composition in each week. No strict control of the hydraulic and SLR was possible due to the variation of the sludge origin, volume and characteristics. The treatment units simply received all the truck content, whatever its volume and characteristics, thus reproducing real operating conditions. Every truck had a small device to check the amount of volume applied, and the volumes varied from 3 up to 10 m^3, but typically 8 m^3. For an applied volume of 8 m^3 in the full-scale unit, the resulting HLR was $8\ m^3/29.1\ m^2 = 0.275\ m^3\ m^{-2}$ per application $= 0.275\ m^3\ m^{-2}\ week^{-1} = 14.3\ m^3\ m^{-2}\ year^{-1}$. From this value, the resulting HLR to be applied in the pilot units was calculated.

The experiment was based on receiving the full volume of the incoming truck, calculating the resulting HLR on site, and only later on measuring total solids (TS) in the laboratory, and then calculating the resulting solids loading. In the pilot units, the HLR was based on the HLR applied in the full-scale unit, and readjusted in order to reflect the same HLR, half HLR or double HLR, as explained in the section above. This calculation was done depending on the volume received each week. For the typical condition of the truck full of sludge (8 m^3), the volume applied in each column was 4.5 L in PW1, PW2, PW5 and PW6 (same HLR); 2.3 L in PW3 (half HLR) and 9.1 L in PW4 (double HLR). The samples to evaluate effluent quality were collected at the outlet of the full-scale beds through a perforation at the bottom of the pilot-scale units.

Normally in Brazil, and in many developing countries, the companies in charge of transporting and disposing of septic tank sludge do not have control of the characteristics of the incoming influent. In this particular study, this led to lack of control of the applied loads, from a strict research point of view. However, these variations reproduced real conditions that may occur at full scale in many municipalities.

Monitoring

The performance evaluation was conducted through monitoring of physical–chemical parameters from the applied sludge, percolate from the sludge units and effluent from the units that received percolate for further treatment. TS, total volatile solids (TVS), chemical oxygen demand (COD) and biochemical oxygen demand (BOD_5) were monitored. The parameters were determined following *Standard Methods for the Examination of Water and Wastewater* (APHA/AWWA/WPCF 2005).

At the end of Phase 1 and Phase 2, sludge accumulated on the top of the units was studied. For the case of the full-scale unit, height measurement was done at each 3 m along the length of the unit.

General appearance of the plants and adaptation to the climate and substrate conditions was observed. The height of the plants in the pilot and full-scale units was measured at the end of the two phases of this research. In addition, the density of the plants was evaluated at the end of Phase 1 for the pilot units in order to check the performance of *Cynodon* spp. for the different HLR and SLR applied.

A descriptive statistical analysis was done from the results of quality monitoring during the two phases of this research. For Phase 1 of the research, an analysis of variance (ANOVA) test based on models with random effects or mixed models was done in order to analyse the comparison of the performance of the units for removal of physical–chemical parameters. For Phase 2, an ANOVA test based on a regression model was used in order to evaluate the general efficiency of the system as well as the recirculation of the percolate. The statistical analysis was done using the software R and was interpreted at a significance level of 5%.

RESULTS AND DISCUSSION

SLR

Owing to the varied septage origins (households, bakeries, condominiums, toilets, etc.), the SDRB units were operated at very different SLR. Figure 2 shows the large variability of the resulting SLR at each application in the full-scale units during Phase 2.

With the loading criteria explained in the 'Methods' section, the resulting values of the applied SLR in Phase 1 were in the range from 10 to 172 kg TS m^{-2} $year^{-1}$ (median value of 12 kg TS m^{-2} $year^{-1}$) in the full-scale unit FSW#1 and in the pilot units PW1, PW2, PW5 and PW6, respectively; from 5 to 86 kg TS m^{-2} $year^{-1}$ (median value of 5 kg TS m^{-2} $year^{-1}$) in PW3 and from 20 to 344 kg TS m^{-2} $year^{-1}$ in PW4 (median value of 22 kg TS m^{-2} $year^{-1}$). In Phase 2 they were in the range from 10 to 879 kg TS m^{-2} $year^{-1}$ in FSW#1 (median value of 18 kg TS m^{-2} $year^{-1}$ and mean value of 75 kg TS m^{-2} $year^{-1}$). No strict control of HLR and resulting SLR were possible, thus reproducing real conditions found in most real plants in developing countries, in which the incoming sludge volume and load are commonly uncontrolled in each application.

Septage or faecal sludge studies held in SDRB units suggest different optimum values of SLR and its application; however, all of the authors indicated optimal SLR that are much higher than those found in Phase 2 of this research. For instance, Koottatep *et al.* (2004) suggested an optimum operation condition at a SLR of 250 kg TS m^{-2} $year^{-1}$ (or constant volume loading of 8 m^3 $week^{-1}$) in units planted with *Typha augustifolia*, with 6 days of percolate impoundment. Conversely, Troesch *et al.* (2009) recommended a loading rate of 30 kg SS m^{-2} $year^{-1}$ in pilot units planted with *Phragmites australis* with a maximum of 3 days feeding period and 20 days of rest without risk of reeds wilting in summer.

In general, the sludge from ST in this study was more diluted than that reported in the international literature. The diluted characteristics of septage might be associated with the suction (by trucks) of the supernatants of these ST; similar findings were obtained by Tachini *et al.* (2006).

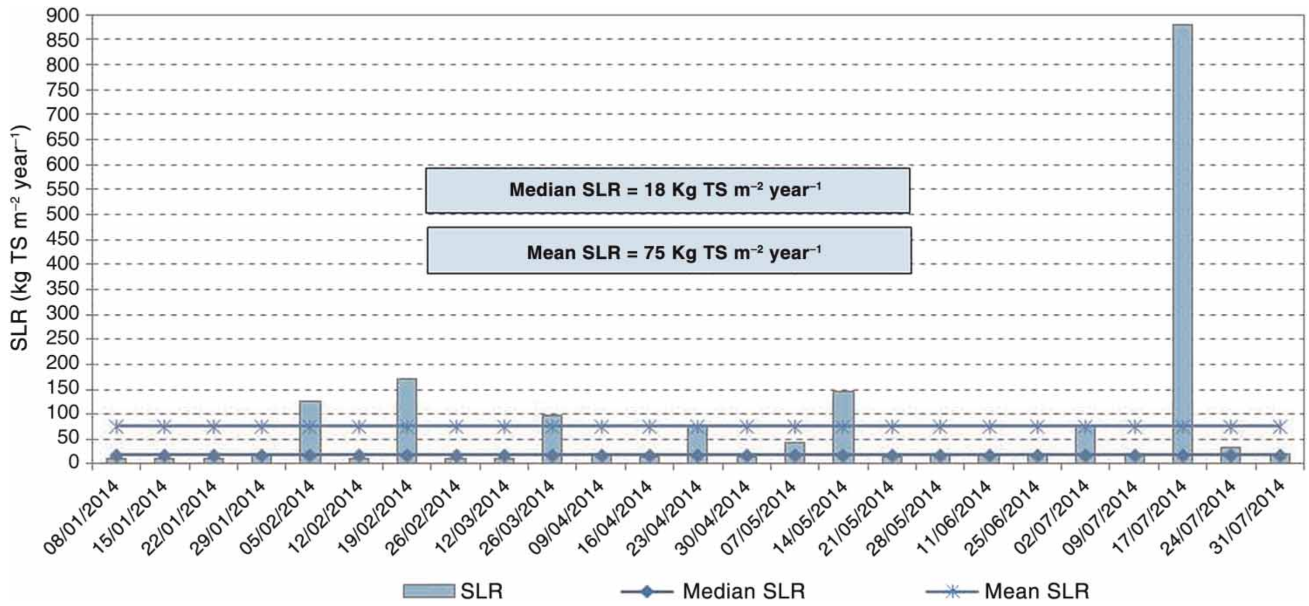

Figure 2 | SLR at each application in the full-scale unit during Phase 2.

Normally sludge removed by pumping in ST is generally less viscous and more diluted than that manually collected (Strande *et al.* 2014).

Physical–chemical parameters

The results emphasize the great variability in the septic sludge composition in terms of organic matter and solids. Owing to the large variation of the results, the median was used as a measure of central tendency. The results can be seen in Table 1 for Phase 1 (full-scale and pilot units) and in Table 2 for Phase 2 (full-scale unit).

The results obtained for the raw septage in Phase 1 correspond to a very diluted septage for the reasons mentioned previously, since the TS (706 mg L^{-1}), TVS (377 mg L^{-1}), COD (487 mg L^{-1}) and BOD_5 (302 mg L^{-1}) values are all in the range of typical domestic wastewater characteristics, according to von Sperling (2007). The data available in the literature show a large variation in relation to the quality of sludge from ST. Some authors observed much higher

Table 1 | Physical–chemical characteristics of the septic tank sludge (raw septage) and filtered effluent (percolate) from full-scale (FSS) and pilot-scale (PSS) units for Phase 1

Unit of measurement	Parameter	Descriptive statistics	Raw septage	FSW#1	FSW#1 + R	PW1	PW2	PW3	PW4	PW5	PW6
Concentration (mg L^{-1})	TS	Median	706	612	676	705	600	733	610	622	689
		Stand.dev.	*4,354*	*343*	*388*	*892*	*258*	*801*	*335*	*232*	*393*
	TVS	Median	377	264	280	311	298	295	304	291	298
		Stand.dev.	*3,759*	*258*	*295*	*590*	*192*	*634*	*277*	*199*	*330*
	COD	Median	487	270	246	328	371	370	348	334	461
		Stand.dev.	*9,800*	*429*	*410*	*952*	*422*	*1,501*	*602*	*459*	*788*
	BOD_5	Median	302	177	159	198	221	200	241	180	227
		Stand.dev.	*2,995*	*327*	*299*	*328*	*450*	*405*	*497*	*257*	*519*
Removal efficiency (%)	TS	Median		22	27	14	19	10	19	14	1
		Stand.dev.		*33*	*44*	*34*	*33*	*35*	*34*	*36*	*40*
	TVS	Median		32	47	26	25	26	36	35	19
		Stand.dev.		*49*	*36*	*36*	*48*	*46*	*54*	*38*	*51*
	COD	Median		41	71	41	37	37	35	41	26
		Stand.dev.		*27*	*29*	*40*	*32*	*33*	*32*	*33*	*54*
	BOD_5	Median		59	68	43	35	41	39	44	40
		Stand.dev.		*24*	*27*	*24*	*23*	*23*	*22*	*25*	*25*

Table 2 | Physical–chemical characteristics of the septic tank sludge (raw septage) and filtered effluent (percolate) from the full-scale unit in Phase 2, without and with percolate recirculation

Unit of measurement	Parameter	Descriptive statistics	Raw septage	FSW#1 (without recirculation)	FSW#1 + R (with recirculation)
Concentration (mg L^{-1})	TS	Median	1,563	1,014	1,166
		Standard deviation	*12,313*	*835*	*541*
	TVS	Median	943	523	673
		Standard deviation	*11,824*	*312*	*329*
	COD	Median	2,301	460	409
		Standard deviation	*7,334*	*575*	*401*
	BOD_5	Median	1,025	236	242
		Standard deviation	*3,828*	*461*	*298*
Removal efficiency (%)	TS	Median		44	29
		Standard deviation		*31*	*34*
	TVS	Median		51	37
		Standard deviation		*36*	*43*
	COD	Median		71	74
		Standard deviation		*21*	*30*
	BOD_5	Median		67	73
		Standard deviation		*24*	*22*

values for TS, TVS, COD and BOD_5, respectively: Koottatep *et al.* (2004): 15,350, 11,150, 15,700 and 2,300 mg L^{-1}; Tachini *et al.* (2006): 49,593, 29,685, 23,835 and 11,424 mg L – 1; Ratis (2009): 3,557, 2,480, 3,549 and 973 mg L^{-1}. Finally, Suntti *et al.* (2011) obtained 18,676, 7,996 and 14,666 mg L^{-1} for TS, VS and COD.

According to ANOVA analysis based on mixed models efficiencies, when comparing the results from the full-scale and the six pilot units in Phase 1 it was found that there was no significant difference for the removal of the constituents shown in Table 1. This indicates that, in this particular research, the effects of having or not having plants, making recirculation, having or not having earthworms and the size of the bed were not relevant in terms of removal efficiency, at a confidence level of 95%.

For Phase 2, it was observed that the concentration values in the raw septage for TS (1,563 mg L^{-1}), TVS (943 mg L^{-1}), COD (2,301 mg L^{-1}) and BOD_5 (1,025 mg L^{-1}) were 2.2, 2.5, 4.7 and 3.4 times higher for TS, TVS, COD and BOD_5, respectively, than those found for Phase 1. The ratio COD/BOD_5 of the septage was 1.9, which is in the range of the typical ratio for raw wastewater (1.7–2.4).

In Phase 2, TS (44%) and TVS (51%) removal efficiencies were not as good as for BOD_5 (67%) and COD (71%) removal in the FSW#1. In addition, a large variability can be seen, as shown in Figure 3 for TS and COD. With

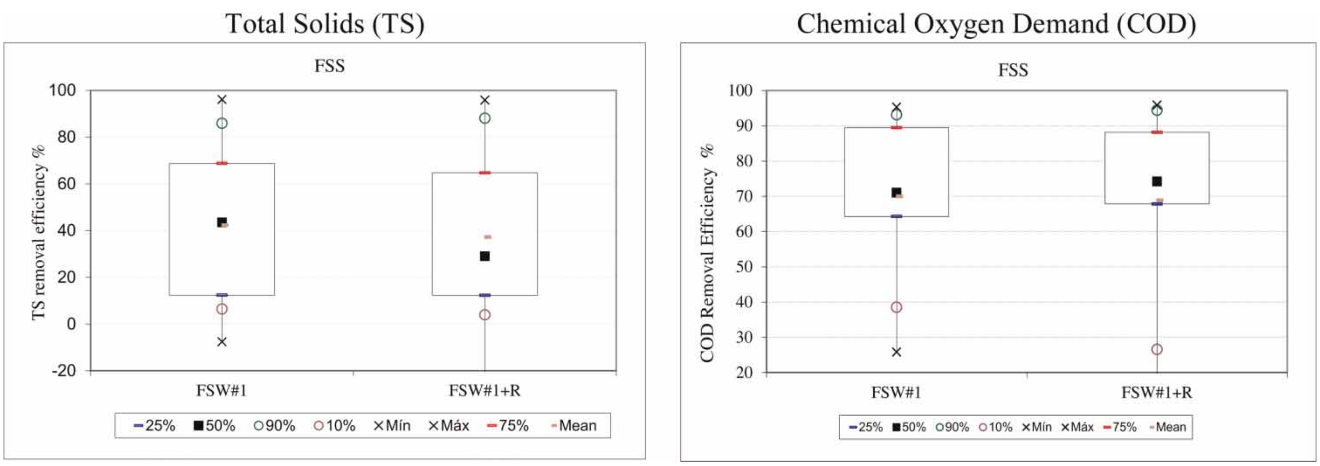

Figure 3 | Box-plot of TS and COD removal efficiencies during Phase 2 in the full-scale unit (FSS), without (FSW1) and with (FSW1 + R) percolate recirculation.

recirculation of the percolate, the median efficiencies for solids showed some decrease, while the efficiencies for organic matter improved slightly. However, the ANOVA test based on regression models indicated that there was no significant difference between the conditions of having or not having recirculation. Even though the full-scale SDRB gave a good contribution in terms of organic matter, the effluent BOD and COD concentrations were still high, suggesting the need for a further treatment step in order to provide a better effluent quality.

The low loading rates and influent concentrations may explain the modest removal efficiencies obtained. According to Kadlec (1997), there is an often and noticed positive relation between loading rate and performance, therefore, the low influent loading rate would explain the low removal efficiencies obtained. Efficiencies achieved by Koottatep *et al.* (2004) and Troesch *et al.* (2009) in their local conditions were much higher; however, the pollutants concentration in their septage were greater than those found in this study. Although removal efficiencies obtained by these authors were high, the percolated effluent was still concentrated and needed a suitable complementary treatment before final disposal, which was also the case in this research. In addition, the inclusion of a fine layer of sand on the top of the units, as is commonly practiced, probably could have improved the effluent quality.

To observe if pollutants efficiencies improve over time, a longer research period would be necessary, since it is expected that filtration improves over time, favoring treatment performance. This is due to the smaller pore size of the formed sludge deposit layer on top of the SDRB in comparison to the size of the granular medium.

Sludge accumulation

At the end of Phase 1 (duration of 2.5 months), sludge accumulated on the top of the units achieved mean thickness values of 3.5 cm, 2.0 cm, 3.0 cm, 3.0 cm, 2.5 cm and 2.0 cm for PW1, PW2, PW3, PW4, PW5 and PW6, respectively, and an average height of 3.0 cm in FSW#1. The accumulated sludge layers were not high enough to enhance filtration effects. At the end of Phase 2, sludge accumulated on the top of FSW#1 reached 10 cm height, corresponding to a rate of 12 cm year^{-1}. This value is equivalent to those reported by Koottatep *et al.* (2004) and Troesch *et al.* (2009), who found the same accumulation rate of sludge, even though solids loading rates were much higher in their research. In spite of the sludge accumulation, the applied sludge could be entirely drained, although at a slower rate.

Monitoring of *Cynodon* spp.

During Phase 1, it was observed that *Cynodon* spp. was very well adapted in the pilot and full-scale units. The overall average stem length was in the range from 0.70 to 0.74 m, with similarities in the units, suggesting that the HLR and SLR were not influential on this respect. Conversely, the average height of the plants in the full-scale unit was around 1.0 m. The physical characteristics, like color of the plant leafs, were similar for both systems, showing comparable healthy appearance and signs of wilting when there was no feeding of septage (2 weeks of interruption along the study period) and when average air temperatures in the area were higher than 30 °C. For very low HLR, such as the one in PW3, there were signs of water deficiency in the plants, leading to wilting of the leaves and eventual death of the plants.

Before starting Phase 2, one pruning was performed in the full-scale unit. The characteristics of the plants were similar to those found in Phase 1, but the average height of the plants was 0.45 m, lower than that in Phase 1. It must be pointed out that there was animal presence (horses and cows) in the surrounding area of the SDRB units, and they occasionally fed themselves on the plants. In addition, some invasive species have grown in the system, but after 2 months they died, reaffirming the resistance of *Cynodon* species for this application.

CONCLUSIONS

The incoming septage monitored was, in general, more diluted than expected and reported in the literature, showing different characteristics in its composition and satisfactory biodegradability. The incoming sludge presented median values in Phase 1 (feeding of pilot and full-scale units) of 706 mg L^{-1}, 377 mg L^{-1}, 487 mg L^{-1}, 302 mg L^{-1} and in Phase 2 (feeding of full-sale unit) of 1,563 mg L^{-1}, 943 mg L^{-1}, 2,301 mg L^{-1}, 1,025 mg L^{-1} for TS, TVS, COD and BOD$_5$, respectively.

Because of the low concentration of the influent sludge, the resulting SLR applied were much lower than those reported in the literature for septic tank sludges in SDRB units. The SLR values for Phase 1 had median values of 12 kg TS m^{-2} year^{-1} in the full-scale unit, and in the pilot units with half and double the HLR, the resulting values were 5 and 22 kg TS m^{-2} year^{-1}. For Phase 2, the median applied SLR value was 18 kg TS m^{-2} year^{-1}.

In the full-scale unit in Phase 2, the removal efficiencies (median values of 44%, 51%, 67% and 71% for TS, TVS, BOD_5 and COD, respectively) were low for solids and satisfactory for organic matter. However, the effluent concentrations were still high for all parameters, and not likely to comply with most discharge standards in various countries. Naturally, further research needs to be done and longer monitoring periods are needed in order to assess the long-term performance and the effect of recirculation, especially with the biomass development over time, allowing assessment of the positive impact of the sludge layer on the top of the units.

Cynodon spp. showed good resistance to the conditions provided in this research, with weekly sludge feeding periods and tropical conditions, reaching air temperatures up to 30 °C. In the full-scale unit, the plants grew up very fast and reached high lengths with the sludge application.

From the point of view of septic tank sludge disposal and partial treatment, the utilization of a unit of the first stage of the French VFCW, adapted to perform as a sludge drying reed bed, showed good potential for developing tropical climate regions, such as in Brazil, due to the ease of application, construction and operation. However, improvement of the filter bed composition or inclusion of a further treatment step for the percolate may be necessary.

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