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# Swine wastewater treatment using an anaerobic baffled (ARB) and a UASB reactor system

# Sistema reator anaeróbio de chicanas - reator UASB no tratamento de efluentes de suinocultura

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## Abstract

The purpose of this study was to assess the swine wastewater treatment system, consisting of the anaerobic baffled reactor (ABR), followed by the upflow anaerobic sludge blanket (UASB) reactor at full scale. The system was monitored by analyzing samples collected in the influent and effluent of ABR and UASB. The following parameters were analyzed: temperature, pH, total suspended solids (TSS), volatile suspended solids (VSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). Averages of total removal of COD and BOD were 96.7 and 98.4%, respectively. The mean concentrations of COD, BOD, TSS, and VSS at the final effluent were 611, 124, 138, and 134 mg $L^{-1}$, respectively. The mean volumetric organic loadings (VOL) at the ABR and UASB were 10.29 and 0.99 kg COD $m^{-1}d^{-1}$. Therefore, the ABR-UASB system was found to be a promising alternative for the swine wastewater treatment.

**Key words:** Animal waste. Anaerobic digestion. Environmental impact.

## Resumo

O objetivo deste trabalho foi avaliar o sistema de tratamento de águas residuárias de suinocultura, constituído de reator anaeróbio de chicanas (RAC), seguido por reator anaeróbio de manta de lodo (UASB), em escala real. O sistema foi monitorado por meio da análise de amostras coletadas nos afluentes e efluentes do RAC e UASB. Foram analisados os seguintes parâmetros: temperatura, pH, sólidos suspensos totais (SST), sólidos suspensos voláteis (SSV), demanda bioquímica de oxigênio (DBO) e demanda química de oxigênio (DQO). As médias de remoção total de DQO e de DBO foram 96,7 e 98,4%, respectivamente. As concentrações médias de DQO, DBO, SST e SSV no efluente final foram 611, 124, 138 e 134 mg.$L^{-1}$, respectivamente. As cargas orgânicas volumétricas (COV) médias no RAC e UASB foram 10,29 e 0,99 kgDQO m kgDQO $m^{-3}d^{-1}$. Desta maneira, o sistema RAC-UASB apresenta-se como alternativa promissora para o tratamento de águas residuárias de suinocultura.

**Palavras-chave:** Dejetos animais. Digestão anaeróbia. Impacto ambiental.

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## Introduction

World population growth and the consequent increase in per capita food consumption have led to changes in the structure of production systems. In this context, the traditional family farming, characterized by the breeding of a small number of animals, was replaced by a technified system with the capacity to produce large amounts of animal protein in a limited physical space. In return, the amount of waste generated has increased, which can compromise the quality of air, water, and soil when improperly stored and managed (ABREU NETO; OLIVEIRA, 2009).

According to Seganfredo (2007), swine wastewater dumped into water bodies can lead to eutrophication due to the presence of nitrogen and phosphorus. In addition, loss of biodiversity and transmission of waterborne diseases are other factors against water quality, may occur because of contamination.

In swine confinement buildings, large volumes of effluents are produced, mainly for large herds, where there is an intensive use of water for the sanitation of facilities. At these facilities, the water used for cleaning drains feces, urine, and feed leftovers to a holding tank, which are then dumped into a course of water or disposed onto the soil without discretion, which in excess can cause toxicity (PEREIRA et al., 2009, 2010, 2011; OLIVEIRA; SANTANA, 2011).

Afterwards, the development of upflow anaerobic sludge blanket reactors (UASB) allowed the treatment of a wide variety of wastewater. However, as in other configurations, a UASB reactor is also subject to limitations on hydrolysis of suspended solids in influents, considered harmful to granular sludge formation (OLIVEIRA; FORESTI, 2004; FERNANDES; OLIVEIRA, 2006).

Thus, using a two-stage anaerobic process may be advantageous to treat wastewater with high concentrations of suspended solids. This process consists of two series reactors, one for partial hydrolysis of complex organic material, and another for digesting soluble compounds formed in the first reactor (FERNANDES; OLIVEIRA, 2006).

An anaerobic baffled reactor (ABR) combines the advantages of an anaerobic filter, which presents high stability and safety, and those of a UASB reactor as a phase separator, which ensures high retention of biomass. This type of reactor is highly efficient in retaining the particulate organic fraction, being able to improve the performance and stability of the treatment system (ABREU NETO; OLIVEIRA, 2009; FERNANDES; OLIVEIRA, 2006; SILVA; NOUR, 2005).

In this regard, this study aimed at evaluating the performance of ABR and UASB in series treating swine wastewater with high concentrations of suspended solids.

## Material and Methods

The study was carried out at the Experimental Farm ‘Professor Hélio Barbosa’, located at the School of Veterinary from the Federal University of Minas Gerais (UFMG), in Igarapé / MG, Brazil. We used a full-scale treatment system consisted of an anaerobic baffled reactor (ABR) followed by a UASB reactor, with volumes of 7.2 $m^3$ (4.0m x 1.2m x 1.5m) and 12.4 $m^3$ (2.4m x 1.2m x 4.3m), respectively (Figure 1).

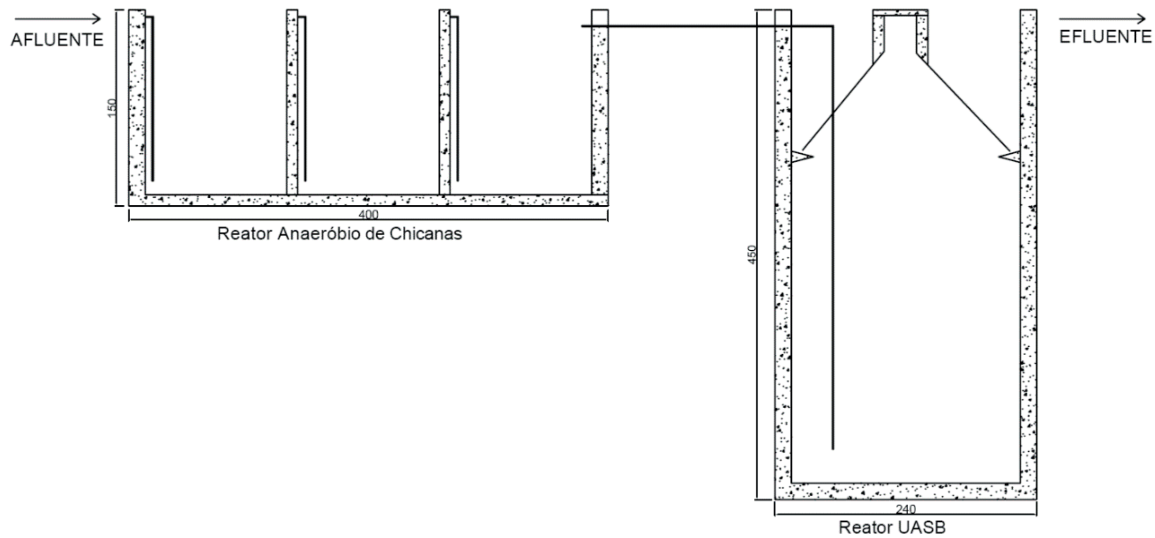
This full-scale wastewater treatment plant (WWTP) was designed to serve the swine sectors of nursery, rearing, and finishing and had the capacity of treating waste generated by a herd of 400 animals. The generated waste was fed to the ABR-UASB reactor system through channels by gravity.

The ABR-USAB system was started up using as inoculum sludge from an anaerobic lagoon, previously used in the treatment of swine wastewater. The initial biological load (BL) was 0.37 kg $kg^{-1}$ $d^{-1}$ [BOD] $[TVS]^{-1}$ $[d]^{-1}$.

The process was monitored by means of physical, chemical, biochemical, and microbiological analyses of crude wastewater and effluents from the ABR and UASB reactor system. The evaluated parameters were air and liquid temperature, pH, BOD, COD, total suspended solids (TSS), and volatile suspended solids (VSS), which were performed as recommended by APHA/AWWA/WEF (2012).

Samples were collected in the morning during the sanitation of facilities. Composite samples were obtained from single samples and conditioned in previously identified glass vials, being collected weekly every 15 minutes for four hours.

**Figure 1.** Diagram of a real-scale treatment system composed of an anaerobic baffled reactor (ABR) followed by upflow anaerobic sludge blanket reactor (UASB).




## Results and Discussion

Table 1 shows the mean values of the physicochemical parameters obtained while monitoring the influent and affluent of the ABR and UASB.

**Table 1.** Mean values, standard deviation (SD), and coefficient of variation (CV) of pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and volatile suspended solids (VSS) for the influent and effluent of ABR and UASB reactors.

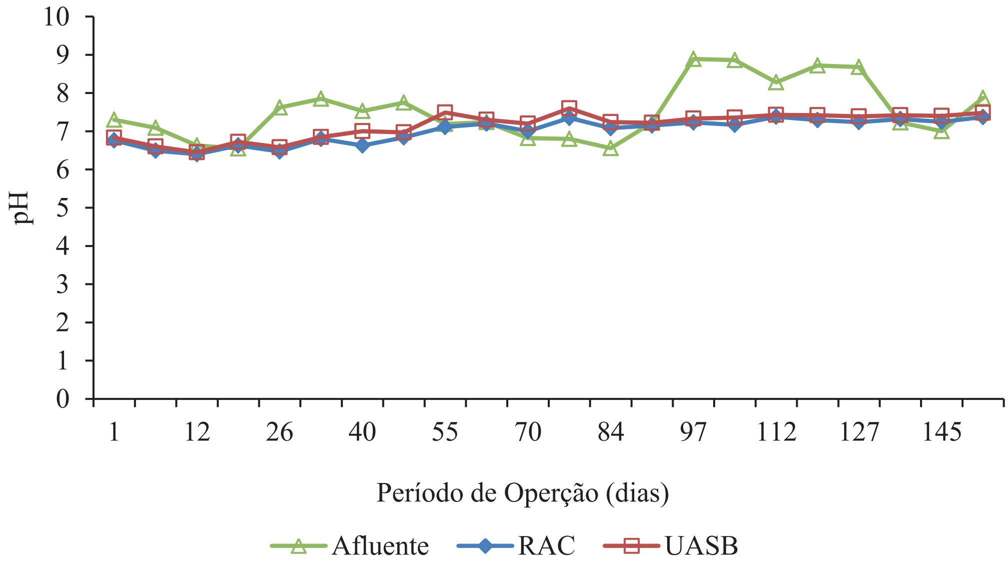
| Parameters | | Standard statistics | | |
|---|---|---|---|---|
| | | Mean | SD | CV |
| pH | Influent | 7.59 | 0.76 | 0.10 |
| | ABR | 7.00 | 0.32 | 0.05 |
| | UASB | 7.14 | 0.34 | 0.05 |
| BOD ($mg.L^{-1}$) | Influent | 5399 | 3276 | 0.61 |
| | ABR | 1071 | 1135 | 1.06 |
| | UASB | 124 | 149 | 1.20 |
| COD ($mg.L^{-1}$) | Influent | 18135 | 6326 | 0.35 |
| | ABR | 2913 | 1514 | 0.52 |
| | UASB | 611 | 223 | 0.36 |
| TSS ($mg.L^{-1}$) | Influent | 5387 | 2409 | 0.45 |
| | ABR | 1030 | 752 | 0.73 |
| | UASB | 138 | 67 | 0.49 |
| VSS ($mg.L^{-1}$) | Influent | 4700 | 2117 | 0.45 |
| | ABR | 879 | 606 | 0.69 |
| | UASB | 134 | 65 | 0.49 |

Throughout the experiment, the mean room temperature was 20 °C, ranging from 12 to 27 ° C. Yet the temperature of effluent was higher than the influent, remaining always above 20 °C, which indicates that both ABR and UASB were operated predominantly within the mesophilic range (20 to 45 ° C).

Fernandes and Oliveira (2006) studied the effect of temperature in UASB reactors treating swine wastewater. The authors noted that the increase and control of the operating temperature, between 25 ° C and 30 ° C, resulted in improved performance and stability of UASB reactors, regarding COD removal, TSS, methane production, and sludge bulking.

The pH values of influent (Figure 2) ranged from 6.6 to 8.9, while in the ABR these values ranged from 6.4 to 7.4. This outcome indicates an acidification of the influent when passing through the ABR. In the UASB reactor, the pH values remained above 7.0, noting that the UASB reactor operated steadily throughout the experimental period.

**Figure 2.** Influent and effluent pH values for the ABR and UASB reactors during the experimental period.



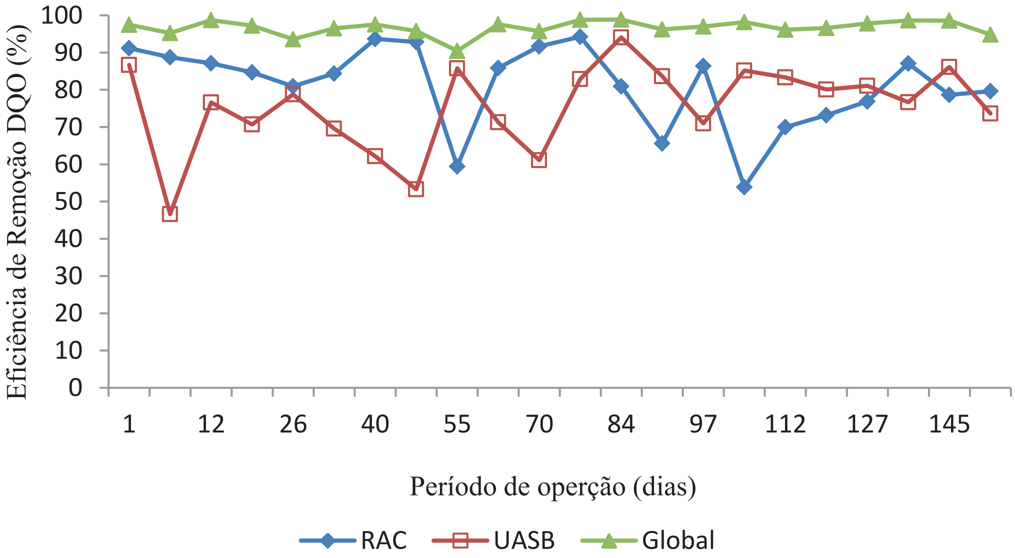

Silva and Nour (2005) observed an ABR reactor treating sanitary sewer, and recorded pH values ranging from 6.7 to 7.0. Mazzola et al. (2005), evaluating the performance of an ABR reactor with two chambers in series on the treating of sanitary sewer, registered pH values ranging from 7.1 to 7.7. The pH values in the ABR recorded in this study were similar to those of Silva and Nour (2005) and Mazzola et al. (2005), varying within the neutrality range, which is considered ideal for the growth of methanogenic microorganisms.

The BOD removal efficiency in ABR ranged from 34 to 97%. This large oscillation during the experimental period occurred due to the TSS and VSS concentration in the influent. The UASB reactor presented efficiency values with lower oscillation, ranging from 70 to 97%, resulting in an overall average system efficiency of 98.4%.

The mean concentrations of COD, BOD, SST, and SSV in the final effluent were 611, 124, 138, and 134 mg $L^{-1}$. Although these values were above the disposal standards set by the CONAMA (National Council of the Environment), the system achieved a significant reduction of pollutants.

The average COD removal efficiency (Figure 3) of ABR for an applied VOL ranging from 4.65 to 14.57 kg $m^{-1}$ $d^{-1}$ of COD and HRT of 1.77 days was 81.2%. The UASB reactor had an average removal efficiency of 75.5% for an applied VOL ranging from 0.31 to 2.24 kg $m^{-1}d^{-1}$ of BOD and HRT of 2.97 days.

**Figure 3.** Efficiency for COD removal of the ABR and UASB reactors, and of the ABR-UASB reactor set, during the experimental period.




The ABR-UASB reactor system had an average removal efficiency of 96.7% for COD, with minor variations, showing high reliability and operational stability.

Abreu Neto and Oliveira (2009), when operating a pilot system consisting of a baffled reactor, followed by a UASB reactor in the treatment of swine effluents, found COD removal efficiencies between 87 and 94% for VOLs ranging from 11.5 to 18 kg $m^{-1}d^{-1}$ of COD in the baffled reactor and from 4.2 to 13.4 kg $m^{-1}d^{-1}$ of COD in the UASB reactor.

Bruno and Oliveira (2008), working on with bench-scale UASB anaerobic reactors in two stages treating wastewater from wet coffee processing, submitted to HRT(?) ranging from 2.0 to 6.2 days and VOL from 0. 4 to 5.8 kg $m^{-1}d^{-1}$ of COD, obtained mean COD and TSS removal efficiencies from 66 to 98% and from 93 to 97%. In turn, Javarez Júnior et al. (2007), while studying an ABR (ABR) treating domestic sewage, obtained a COD removal of 70%.

Duda and Oliveira (2009) assessed the performance of sequencing batch anaerobic reactors (SBARs), at a pilot scale, on the treating of swine wastewater with concentrations of total suspended solids (TSS) of around 10,000 mg $L^{-1}$. The VOLs applied in the first ASBR ranged from 4.43 to 12.75 kg $m^{-1}d^{-1}$ of COD, with average COD and TSS removal efficiencies of 52-86% and 54-87%, respectively.

Rodrigues et al. (2010) evaluated a full-scale UASB reactor treating swine effluent with VOL ranging from 1.1 to 17.5 kg $m^{-1}d^{-1}$ of COD and obtained BOD and COD removal efficiencies of 93 and 92%, respectively.

TSS contents in the influent (Figure 4) for the ABR ranged from 720 to 9000 mg $L^{-1}$. These high values led to a reduction in COD removal efficiency for the ABR, however, insufficient to impair the performance. The values of TSS in influent for the UASB reactor (Figure 5) increased during the experimental period, reaching a maximum value of 3500 0 mg $L^{-1}$, which occurred due to sludge disposal failures in the ABR. However, the efficiency of the UASB reactor was not affected.

**Figure 4.** Contents of total suspended solids (TSS) in the influent during the experimental period.

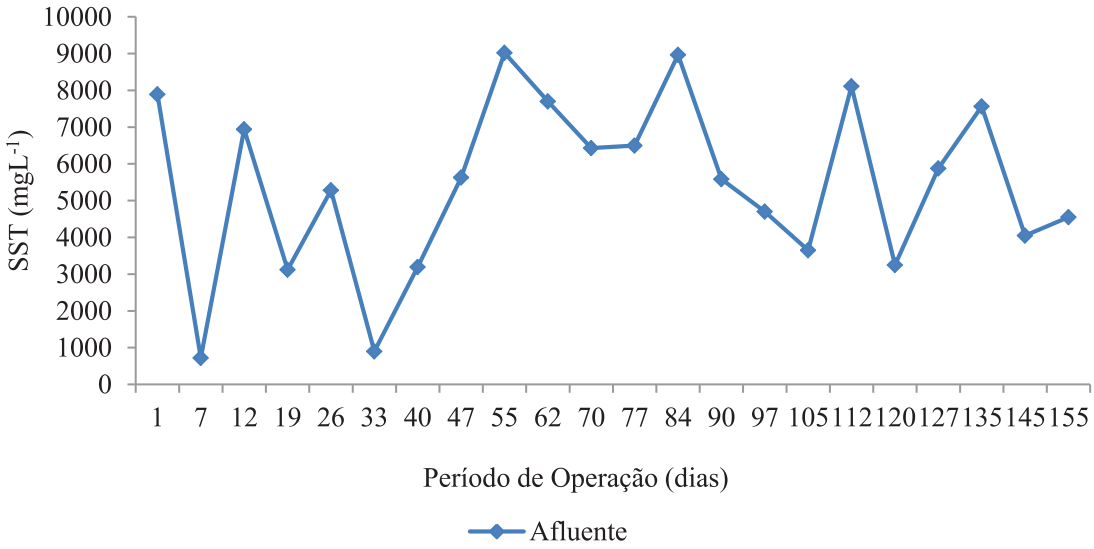
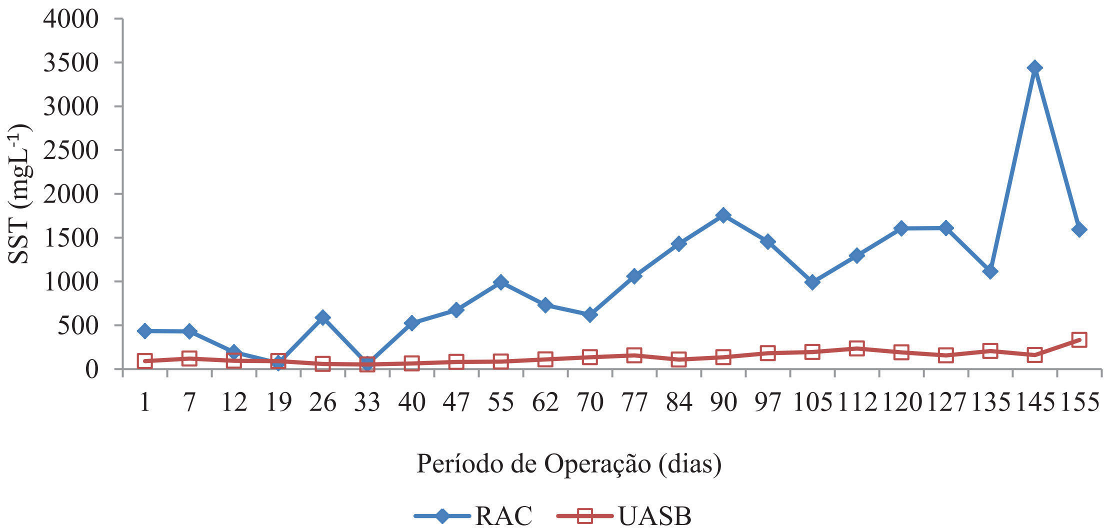



**Figure 5.** Contents of total suspended solids (TSS) in the effluents from the ABR and UASB reactors during the experimental period.




The ABR and UASB reactors presented separately mean TSS removal efficiencies of 77.5 and 75.1%, respectively, and the ABR-UASB reactor system showed a global removal of 98%.

The VSS behavior (Figure 6) was similar to that of TSS. The influent means for the ABR and UASB reactors (Figure 7) were 4700 and 879 mg $L^{-1}$; the mean removal efficiency was 76% in the ABR, and 75% in the UASB reactor, and an overall efficiency of 98%.

The results obtained by the ABR-UASB system for the removal of COD, BOD, TSS, and VSS confirm the advantage of an anaerobic treatment with two reactors in series, showing the robustness and high performance of an ABR reactor as the first stage of the treatment. Even though the ABR received high concentrations of suspended solids, it operated with stability and high-performance, favoring the performance of the UASB reactor.

**Figure 6.** Contents of volatile suspended solids (VSS) in the influent during the experimental period.

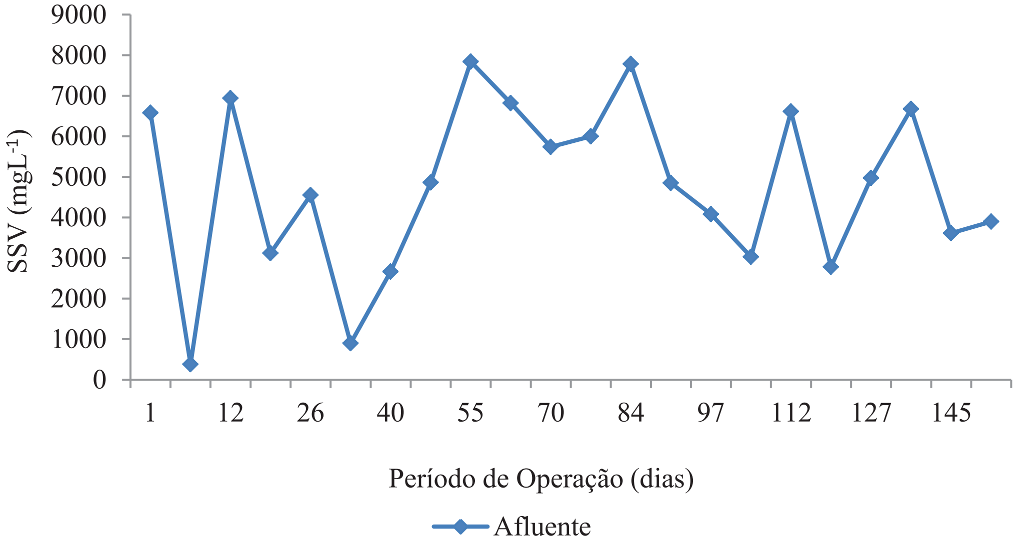
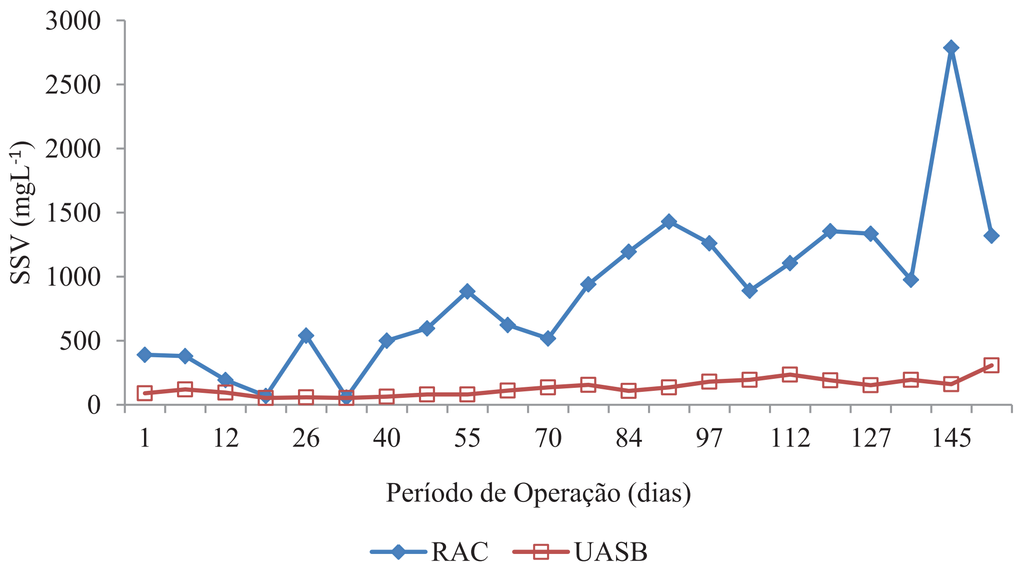



**Figure 7.** Contents of volatile suspended solids in effluents of the ABR and UASB reactors during the experimental period.



## Conclusions

1. The adopted system, composed of an anaerobic baffled reactor (ABR) and a UASB reactor set in series, showed high full-scale efficiency in the removal of organic matter and solids, reaching values above 90% for COD, BOD, TSS, and VSS, thus confirming its feasibility in the treating of swine wastewater.

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