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ANAEROBIC DIGESTION AND THE DENITRIFICATION IN UASB REACTOR

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Abstract: The environmental conditions in Brazil have been contributing to the development of anaerobic systems in the treatment of wastewaters, especially UASB – Upflow Anaerobic Sludge Blanket reactors. The classic biological process for removal of nutrients uses three reactors - Bardenpho System, therefore, this work intends an alternative system, where the anaerobic digestion and the denitrification happen in the same reactor reducing the number of reactors for two. The experimental system was constituted by two units: first one was a nitrification reactor with 35 L volume and 15 d of sludge age. This system was fed with raw sanitary waste. Second unit was an UASB, with 7.8 L and 6 h of hydraulic detention time, fed with ¾ of effluent nitrification reactor and ¼ of raw sanitary waste. This work had as objective to evaluate the performance of the UASB reactor. In terms of removal efficiency, of bath COD and nitrogen, it was verified that the anaerobic digestion process was not affected. The removal efficiency of organic material expressed in COD was 71%, performance already expected for a reactor of this type. It was also observed that the denitrification process happened; the removal nitrate efficiency was 90%. Therefore, the denitrification process in reactor UASB is viable.

Keywords: Denitrification in UASB reactor; anaerobic digestion; post-treatment

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INTRODUCTION

Carbon and nitrogen are the major pollution sources that contribute to environmental quality problems. All of the pollution sources; i.e., municipal, industrial, and agricultural, must be managed in order to reduce the carbon and nitrogen concentration within a certain level to improve the quality of the environment. Problems associated with carbon and nitrogen are (1) imbalance of natural ecological systems and increase of eutrophication, (2) depletion of dissolved oxygen in surface waters which kills fish and create septic conditions, (3) odor problems, (4) contaminants that complicate water treatment, such as ammonia used for water supplies that requires an increase of chlorine dosage to achieve a free chlorine residual in the process of disinfection, and (5) increase risks to human health, such as NO_3^--N concentration in the groundwater for potable use.

Nitrate is regarded as an undesirable substance in public water. Although it occurs naturally in water, elevated levels of nitrate in groundwater usually result from human activities, such as over use of chemical fertilizers in agriculture and improper disposal of human and animal wastes (Cervantes-Carrillo, 2000; Metcalf & Eddy, 2003). High nitrate concentration in drinking water may cause serious problems in humans and animals (Matsuzaka *et al.*, 2003; Moletta, 2005). In order to protect against this matter, the CONAMA (2005) has established the maximum contamination level of nitrate in drinking water at 10 mg NO_3^-N/L, which corresponds to the maximum allowed recommended by the World Health Organization (WHO).

The general treatment alternatives available for the treatment of wastewater can be divided into two major categories: physical/chemical treatment systems and biological treatment systems. Physical treatments include screening, sedimentation, filtration and flotation. Chemical treatments include disinfection, adsorption, and precipitation. The major biological processes used for wastewater treatment can be separated into five major groups: aerobic process, anoxic process, anaerobic process, combined aerobic-anoxic-anaerobic processes, and pond processes. The principal applications of the processes are for removal of the carbonaceous organic matters in wastewater; nitrification; denitrification; phosphorus removal; and waste stabilization. The biological processes are considered the most effective and economic processes in the field of wastewater treatment (Metcalf & Eddy, 2003).

In the anaerobic digestion, the organic nitrogen is reduced, to ammonium form, which is not degraded in those conditions. The most used method for nitrogen removal is the biological treatment by nitrification and denitrification. The nitrification is an aerobic process, accomplished by autotrophic bacteria that promote the oxidation of ammonia to nitrite and nitrate. The second stage of the treatment, named denitrification, is a process in which anaerobic bacteria reduce nitrite and nitrate to molecular nitrogen.

The classic biological process, for removal of nutrients, uses three reactors – Bardenpho System; therefore, this work intends an alternative system, where the anaerobic digestion and the denitrification happen in the same reactor in this system, reducing the number of reactors for two. This work had as objective to evaluate the performance of the UASB reactor, in terms of removal efficiency, of bath COD and nitrogen.

METHODOLOGY

Location

The experiment was carried through in pilot scale in a pertaining area to the *Companhia de Águas e Esgoto da Paraíba* (CAGEPA - UEPB), where about thirty years ago it was set the Experimental Station for the Biological Treatment of Sewage of the Federal University of Campina Grande (EXTRABES-UFCG), City of Campina Grande (7º 13' 11" South, 35º 52' 31" West, 550 m above m.s.l.), Paraiba state, northeastern Brazil.

The treatment system was constituted of two units: the first one is a Submerged Aerated Filter for Nitrification and the second one reactor is a UASB (Upflow Anaerobic Sludge Blanket).

Characteristics of the biological reactors and its operations

Submerged aerated filter for nitrification The Submerged Aerated Filter for Nitrification had 35 L volume and 15 d of hydraulic detention time (HDT). This system was fed with raw sanitary waste and also made use of a secondary decanter, constructed in PVC, of cylindrical form, with diameter 0.10 m and 0.50 m height, with 0.004 m² superficial area. The effluent from this filter was then collected and introduced with a pump in the reactor UASB. **Figure 1** presents the schematic representation and the picture of the Submerged Aerated Filter for Nitrification.

Upflow Anaerobic Sludge Blanket (UASB) With 7.8 L of volume and 6 h of hydraulic detention time, this system was fed with ¾ of effluent submerged aerated filter for nitrification and ¼ of raw sanitary waste. **Figure 2** presents the schematic representation and the picture of the Upflow Anaerobic Sludge Blanket (UASB).

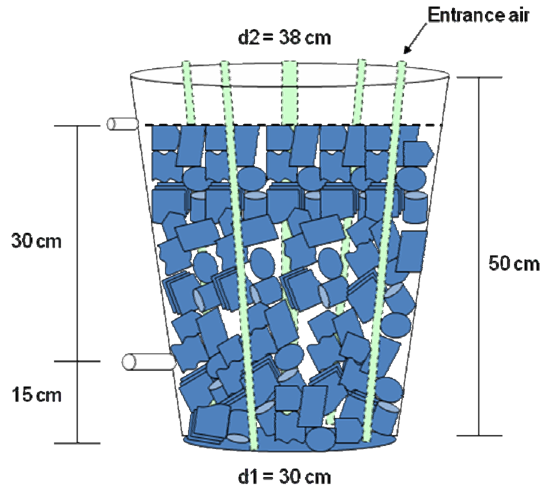

Fig. 1 (a) Schematic representation of determination of dimensions.

Fig. 1 (b) Picture of the Submerged Aerated Filter for Nitrification.

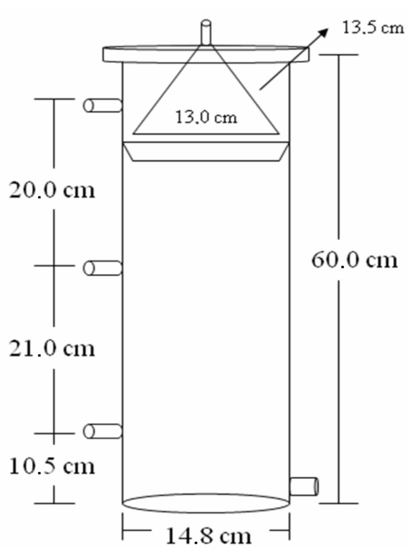

Fig. 2 (a) Schematic representation of UASB reactor.

Fig. 2 (b) Picture of the Upflow Anaerobic Sludge Blanket (UASB).

RESULTS AND DISCUSSION

The physical and chemical analysis in the influent and effluent of UASB reactor were done according to Standard Methods for the Examination of Water and Wastewater (APHA *et al.*, 1998), excepting alkalinity, that had followed the Kapp method (1984) *apud* Buchauer (1998).

Table 1 shows the values of influent and effluents analysis, during 120 d of experiments.

Table 1. Chemical analysis of influent and effluent of UASB reactor

Parameter	Influent of UASB reactor			Effluent of UASB reactor		
	$\bar{x}$		Δ	$\bar{x}$		Δ
pH	7.2	±	0.2	7.5	±	0.4
Alkalinity (mg $CaCO_3$ / L)	214	±	36	253	±	31
COD (mgO_2 / L)	351	±	166	100	±	32
BOD_5 (mgO_2 / L)	155	±	83	44	±	18
TSS (mg / L)	140	±	99	37	±	23
VSS (mg / L)	113	±	77	33	±	21
TKN (mg TKN-N / L)	31	±	7	26	±	5
Ammonia (mg NH_4^+-N / L)	23	±	5	22	±	4
Nitrate (mg NO_3^--N / L)	12	±	4	1.1	±	1
Nitrite (mg NO_2^--N / L)	3	±	2	0.2	±	0.1

The influent pH of UASB reactor was 7.2, whereas pH of the effluent one remained in the band of 7.5, as **Table 1**. Therefore, it can be understood that this reactor did not try great variations of pH, that could compromise its performance in such a way, favoring the development of the metanogenics bacteria that, in accordance with Van Haandel & Lettinga (1994) and Metcalf & Eddy (2003), have an excellent growth in the band of pH between 6.6 and 7.4 and of the denitrificants bacteria that according to Barnes & Bliss (1983), have a better performance in pH 6.5–7.5. The alkalinity varied from 214 mg $CaCO_3$ / L, to 253 mg $CaCO_3$ / L, effluent, as values observed in **Table 1**. The reduction of the concentration of acid volatile (73 for 35 mg HAc / L) indicates that the metanogenic phase of the system were bigger in relation to the acetogenic, indicating good degradability of the organic substance since these acids are transformed into methane and carbon dioxide in anaerobic digestion that can be consumed in the denitrification process. The system presented values 0.34 influent and 0.1 effluent for AGV/alkalinity relation; therefore, the stability of the reactor was kept. According to Hirata (1997) *apud* Isoldi et al. (2005), this relation must be between 0.1 and 0.35 for a good reactor performing.

The stability of pH also can have influenced in the good removal of carbonaceous material: 71% removal of COD and 72% BOD_5, as observed in **Figs 3** and **4**. These figures present the concentrations of COD and BOD_5 effluent and the respective removal efficiencies.

According to Metcalf & Eddy (2003), the relation BOD_5/COD must be in the band of 0.4–0.8 so that the sewer is of easy biodegradation. In this work, this influent and effluent relation was of 0.4. This fact can be an undesirable factor if the effluent is launched in waters surface, therefore, quickly could be oxidized, diminishing the oxygen dissolved, being able to harm the aquatic life. On the other hand, the effluent quality, in terms of N and P, seems to be suitable for irrigation as a nutrient source, therefore, representing a significant fertilizer economy.

The total suspended solids had presented 140 concentrations of mg / L influent and 37 mg / L effluent, resulting in removal efficiency of 74%; while the volatile suspended solids had corresponded 80% of the total suspended solid fraction (113 mg / L) influent and 89% effluent (33 mg / L), showing a removal of 71%.

The solid removal in reactor UASB occurs for two reasons: the process of anaerobic digestion, that forms methane (methanization) and the denitrification process, mainly in the removal of the suspended solids that more quickly to biodegradated if presenting in the necessary form for the bacterial assimilation.

Figure 5 presents the behavior of the concentration influent and effluent the oxidated nitrogen forms (nitrate + nitrite) the efficiency of removal presented for reactor UASB. It is perceived that the efficiency of denitrification presented for the reactor was well steady, demonstrating considerable degree of adaptability of the silt how much to the denitrification process.

The concentrations of influent and effluent of nitrate had been, respectively, 12 and 1.1 mg NO_3^--N / L, and nitrite concentrations had been, 3 mg NO_2^--N / L influent and 0.2 mg NO_2^--N / L effluent. The efficiency of removal of these oxidated nitrogen forms was of 91%. Relation COD/NO_3^-- N was 22. According to Çeçen & Gonenç (1992) and Chui *et al.* (2000), the highest nitrogen removal rates occur when this relation is higher or equal to 5; therefore, it can be observed that the available organic material was enough for the good performance of denitrification in the reactor.

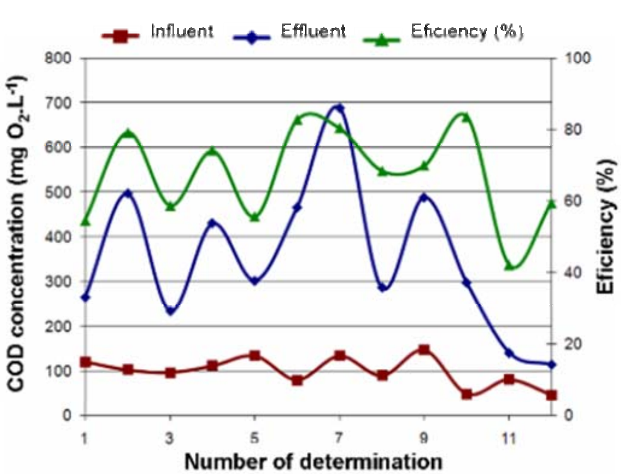

Fig. 3 COD influent and effluent of UASB reactor.

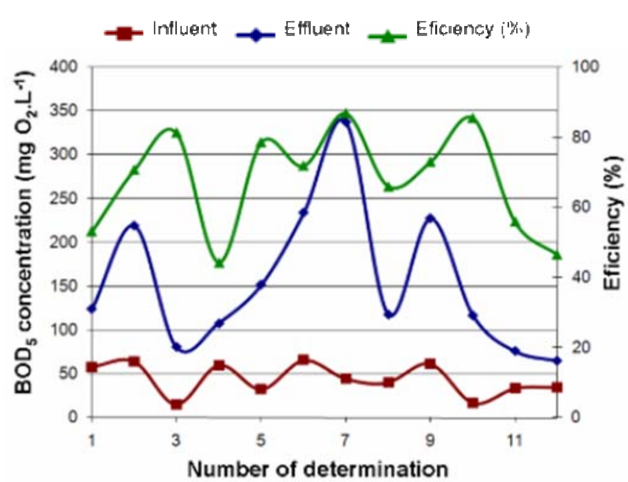

Fig. 4 BOD_5 influent and effluent of UASB reactor.

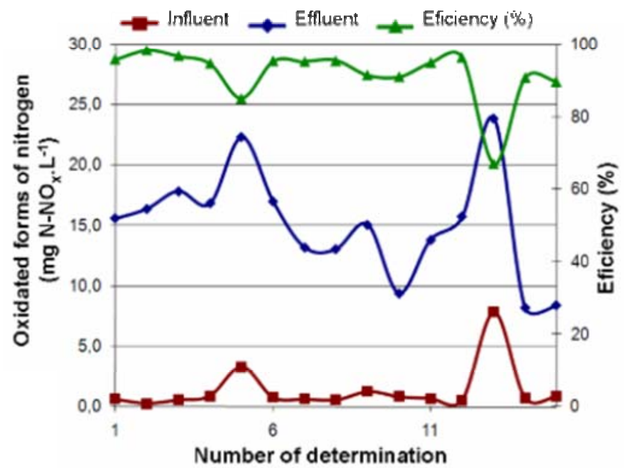

Fig. 5 Oxidation forms of nitrogen concentrations influent and effluent of reactor UASB.

Lopes *et al.* (2001), treating effluent with equal relation COD/NO_3^--N 11, in reactor UASB, had gotten efficiency of 82% nitrate removal and had increased in the nitrite concentration. Isoldi *et al.* (2005) also had dealt with effluent the processing of rice in reactor UASB and had gotten similar efficiency of removal, 87% of nitrate and for nitrite 51%, with relation $COD/N\text{-}NO_3^-$ of approximately 12. A pilot-scale partially aerated biological aerated filter (BAF) was set up, by Ha & Ong (2007), with an anaerobic, anoxic and oxic zone, the influent sCOD and total nitrogen concentrations in the feedwater were approximately 250mg / L and 35 mg NH_4^+-N / L, respectively, $sCOD/N\text{-}NO_3$ 7, with a 75% removal of total nitrogen.

The concentrations of influent and effluent TKN had been, respectively, 31 and 26 mg NTK-N / L the ammoniac nitrogen concentrations had been 23 mg NH_4^+-N / L influent and 22 mg NH_4^+-N / L effluent. It is perceived that it did not have significant removal of these nitrogen forms, presenting concentration sufficiently raised in the effluent. This increase is due to the mixture of raw sanitary waste in the entrance of the reactor.

The external carbon source favored the optimal performance in the nitrate removal, whereas the effluent presented considerable concentrations of total kjeldahl nitrogen and ammonia nitrogen.

CONCLUSIONS

The efficiency of nitrate removal was of 90%, with addition of external carbon source, indicating the viability operational technique of simultaneous occurrence of the metanization process and denitrification in the same anaerobic sludge blanket reactor.

The efficiency removal of carbon material, expressed in COD that occurred in the UASB reactor, was approximately 71%, and the BOD_5 removal was 72%; these values are the ones found in literature; therefore, the process of metanization in this system was not damaged.

REFERENCES

APHA. AWWA. WPCF. (1998) *Standard Methods for the Examination of Water and Wastewater*. 20 edn. Washington, DC.: American Public Health Association. American Water Association. American Waster Works Association, Water pollution Control Federation.

Barnes, D. & Bliss, P.J. (1983) Biological control of nitrogen in wastewater treatment. E. & F. N. Spon. London. 327 p.

Buchauer, K.A. (1988) Comparison of two simple titration procedure to determine volatile fatty acids in effluents to wastewater and sludge treatment process. *Water SA* **24**(1), 49–56.

Çeçen, F. & Gonenç, I.E. (1992) Nitrification-denitrification of high-strength nitrogen waste in two upflow submerged filters. *Water Sci. Technology* **26**(9-11), 2225–2228.

Cervantes-Carrillo, F. (2000) Avances en la Eliminación Biológica del Nitrógeno de las Aguas Residuales. *Revista Latinoamericana de Microbiología*, **42**, 73–82.

Chui, P.C.; Terashima, Y.; Tay, J.H.; Ozaki, H.; Jeyaseelan, S. (2000) Nitrogen removal in a submerged filter with no effluent recirculation. *Water Sci. and Technology* **42**(3-4), 51–58.

CONAMA (2005), Resolução n° 357. 17/03/ 2005. Brasil.

Ha, J.H. & Ong, S.K.F. (2007) Nitrification and denitrification in partially aerated biological aerated filter (BAF) with dual size sand media. *Water Sci. and Technology* **55**(1-2), 9–17.

Isoldi, L.A.; Koetz, P.R.; Isoldi, L.A. (2005) Pós-tratamento de efluente nitrificado da parboilização de arroz utilizando desnitrificação em reator UASB. *Revista Engenharia Sanitária e Ambiental* **10**(4), 271–277.

Lopes, L.F.; Koetz, P.R.; Santos, M.S. (2001) Denitrification on the top of UASB reactors of rice wastewaters. *Water Sci. and Technology* **44**(4), 79–82.

Matsuzaka, E., Nomura, N., Nakajima-Kambe, T., Okada, N., Nakahara, T. (2003) A Simple Screening Procedure for Heterotrophic Nitrifing Bacteria with Oxygen-Tolerant Denitrification Activity. *J. Biosci. and Bioengng* 95(**4**), 409–411.

Metcalf & Eddy. (2003) *Wastewater Engineering: treatment, disposal, reuse*. 5th edn. McGRAW-HILL, Singapore.

Moletta, R. (2005) Winery and distillery wastewater treatment by anaerobic digestion. *Water Sci. and Technology* 51(**1**), 137–144.

Van Haandel, A.C. & Lettinga, G. (1994) *Tratamento anaeróbio de esgotos*. Campina Grande: Epgraf.