Performance of an Upflow anaerobic sludge blanket reactor for hospitals' wastewaters treatment in Colombia: A preliminary study

Desempeño de un reactor anaerobio de manto de lodos y flujo ascendente para tratamiento de aguas residuales hospitalarias en Colombia: Estudio preliminar

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Abstract

Introduction— The hospitals' wastewater is considered harmful to the environment and public health, which demands the utilization of proper treatment systems to manage the pollutants in them.

Objectives— This study evaluated the performance of an anaerobic reactor Upflow Sludge Blanket (UASB) to treat real Hospitals' Wastewater (HWW).

Methodology— The reactor operated for 145 days with variations of the amount of Organic Load Rate (OLR).

Results— The results showed that for mean organic load rate (OLR) of 0.950 Kg COD/m^3 · d the removal efficiency of organic matter was 59% ± 14%, however, the process was unstable and showed low methane gas production.

Conclusions— As a result, this research found that UASB standard systems are not reliable and proper treatment technologies y for treating organic pollutants of hospitals' wastewater.

Keywords— Anaerobic Digestion; recalcitrant compounds; UASB; water treatment

Resumen

Introducción— Las aguas residuales hospitalarias son consideradas peligrosas y dañinas para el medio ambiente y la salud pública, lo que exige la utilización de sistemas de tratamiento adecuados para controlar los contaminantes en ellas.

Objetivos— Este estudio evaluó el desempeño de un reactor anaerobio de Manto de Lodos y Flujo Ascendente (UASB) para tratar Aguas Residuales Hospitalarias reales (HMC).

Metodología— El reactor operó durante 145 días variando los valores de la Carga Orgánica Volumétrica (COV).

Resultados— Los resultados mostraron que para valores medios de carga de 0.950 Kg DQO/m^3 · d la eficiencia de remoción de materia orgánica fue 59% ± 14%, sin embargo, el proceso fue inestable y mostró una baja producción de gas metano.

Conclusiones— Como resultado, esta investigación encontró que el reactor convencional tipo UASB no es una tecnología de tratamiento confiable y adecuada para el tratamiento de materia orgánica presente en las aguas residuales de los hospitales.

Palabras clave— Digestión Anaerobia; compuestos recalcitrantes; UASB; tratamiento de agua

I. Introduction

Hospitals produce approximately 750 liters of wastewater per bed-day, liquid residuals with pathogen microorganisms, pharmaceutical products, metabolized radioactive elements, and other toxic chemical substances. The pollutant doses derived from hospitals evidenced dangerous substances such as antitumoral agents, antibiotics, organ halogenated compounds, and emergent compounds that provoke biological disequilibrium because are not properly treated [1], [2]. Nowadays, in many countries, these kinds of contaminants are not regulated, what motivated to academia researching the effects of human and environmental health. In many countries do not exist legal requirements before the discharge, consequently, the management of this type of wastewater is the same as urban wastewater [3].

In Colombia, there is a strong tendency to dispose of these waters directly to the sewage system with a later treatment in conventional plants, because of the lack of research about the nature and behavior of these effluents for selecting the appropriate technology. Authors [4] and [5] characterized several hospital effluents and compared them against urban wastewaters. They found that hospital wastewater exceeded about 2 and 150 times the reported water quality parameters of urban wastewater.

Because he emergency of the SARS (severe acute respiratory syndrome) occurred in China during 2003, scientists should perform studies to identify safety measurement protocols to prevent infection when handling Urban Wastewaters (UWW), in particular when these UWW do not have a prior treatment [7]. Recently, the IWA alerted that the virus COVID-19 can be present in the hospital effluents. This is a critical warning because the nowadays installed technologies are not designed to remove this emerging pathogen, as a result, the virus could propagate inadvertently among the population [8].

At this time, there are no specific treatments capable to remove all the present micropollutants in hospital effluents, because of the superfluous understanding of their behavior during the treatment process. Usually, these effluents are treated together with urban wastewaters, then, co-treatment of the hospital and urban wastewater is a common practice. However, that strategy reveals more disadvantages than advantages, for example, urban wastewater contains substances that could inhibit the biological process reducing the removal efficiency.

Some research [2] evidenced that microbial resistance, the presence of new emerging compounds, and microorganisms require the combination of biological and physical-chemical treatments as a sustainable strategy. The treatment of wastewater with pharmaceutical compounds has been studied using anaerobic processes, most of them showed results with specific substances, such as antibiotics, antipyretic, and other drugs [9], [10]. Some [5] showed in their study that using effluents previously treated with Advanced Oxidation Processes (AOP) enhanced the biodegradability and the organic matter removal of the anaerobic process. Others [11] studied the influence of organic loads on the performance and structure of the microbial community in a UASR reactor for pharmaceutical wastewater treatment and found that bacteria contributed to the degradation of organic substances of the wastewater. Also, in particular [12] it was shown that combining AOP with a Horizontal Anaerobic Immobilized Biomass reactor (HAIB) to treat real hospital wastewater can reach a COD removal higher than 90%.

The literature review revealed the opportunity for enhancing the traditional anaerobic technologies and the lack of information in Colombia related to the treatment of real hospitals' wastewater by UASB reactors, as a result, this research studied the performance of an anaerobic reactor (UASB) during pollutant removal. Then, it was assessed the efficiency of the UASB reactor removing organic material from real hospital wastewater in terms of COD, Methane gas production, and alkalinity index.

II. Material and Methods

A. *UASB reactor*

The UASB reactor was built in acrylic, with 50 mm of diameter and 590 mm of height, a useful volume of 940 mL, and an L/d ratio of 12. The utilized inoculum belongs to a UASB reactor that treats urban wastewater in Bogotá (Colombia). The reactor was operated with 21 ± 4 of Hydraulic retention time (HRT) and controlled by a peristaltic pump (Masterflex L/S brand) with a flux range between 0.6 and 3400 mL/min; Fig. 1 depicts the assembled experiment.

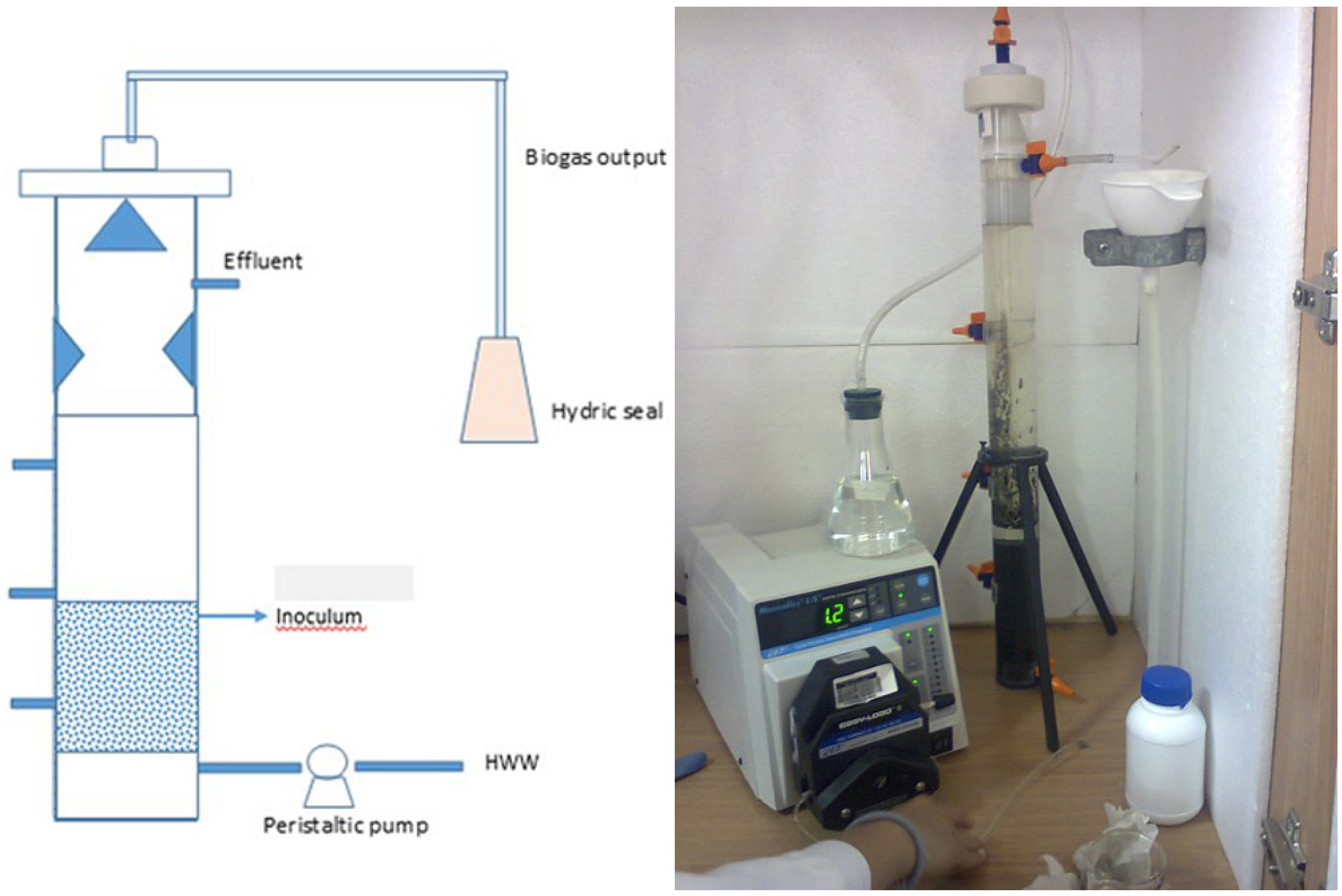

Fig. 1. Setup of the UASB reactor.
Source: Authors.

The UASB reactor operated continuously for 145 days where a feeding strategy was performed through the variation of Organic Loading Rate (OLRs) as follows:

- *Phase* 1: ORL of 0.043 $KgCOD/m^3 \cdot d$ for 13 days, fed with synthetic residual water prepared according to the recommendations [13].
- *Phase* 2: ORL of 0.950 $KgCOD/m^3 \cdot d$ during 135 days, fed with a mix of 75% of synthetic residual water and 25 % of hospital wastewater.

It is important mentioning that during the experiment, the 89-th day reported a temperature increment up-to 50ºC for 24 h in the reactor chamber, which could have generated instability in the biological process.

B. *Hospital wastewater (HWW)*

The Hospital wastewater comes from a Health Central Care (HC) located in Bogotá city. The HC has 397 beds for medical treatments, surgical interventions, external health consulting. The HC produces wastewater derived from human excretions combined with pharmaceutical residuals and detergents. At the present, the wastewaters receive a preliminary treatment through a coarse material removal through gratings, followed by a floater tank and a distributor tank connected to the city's sewage system.

Three samplings of HWW were done for one year, once the samples were collected, preserved, and stored at 4ºC for further analysis. Also, were analyzed physical and chemical parameters such as Total Suspended Solids (TSS), Volatile Suspended Solids (TDS), Total Solids (TS), Alkalinity, Color, UV_{254}, sulfates, Total Kjeldahl Nitrogen, phosphates, BOD_5, COD, and pH according to [14], [15].

C. *Methods*

The stability of the anaerobic digestion was carried out as suggested [16]: COD, Total Volatile Acids (TVA), Total Alkalinity (TA), Partial Alkalinity (PA), Intermediate Alkalinity (IA), Total Solids (TS), Suspended Solids (SS), Total Volatile Solids (TVS), Volatile Suspended Solids (VSS) and pH. These analyses were done by duplicated three times per week. The composition of the biogas was analyzed using a Gas Chromatographer - Agilent 7890-A chromatographer Carboxen 1010 Plot column.

III. Results and Discussion

A. *Characteristic of the Hospital Wastewater (HW)*

The concentrations of pharmaceutical residues in hospital effluents are the result of the combination of three important factors: administered quantities, percentage excreted by each patient, and physicochemical properties of the used drugs [17], [4]. Despite there is no defined pattern of the water quality of these wastewaters but is well known the presence of dissolved emerging compounds discharged into the sewage network.

Table 1 shows the characteristics of the HW used in this study. The results noticed a high dispersion in most of the evaluated parameters Also, the identified value of the biodegradability ratio confirmed the high presence of recalcitrant compounds, most of them recognized as emerging compounds.

Table 1. Characterization of HWW.

Parameter	Unit	Mean ± S.D.
COD	mg/L	286 ± 136
BOD_5	mg/L	48 ± 36
COD/BOD_5		8.03 ± 4.05
pH		7 ± 0.5
Total Alkalinity	mg $CaCO_3$/L	357 ± 79
$Color_{(465nm)}$	cm^{-1}	0.15 ± 0.11
UV_{254}	cm^{-1}	0.60 ± 0.45
TS	mg/L	392 ± 124
TSS	mg/L	30 ± 12
VSS	mg/L	95 ± 55
SO_4^{-2}	mg SO_4^{-2}/L	77 ± 74
Orthophosphates	mg PO_4^{-2}/l	7 ± 4
TKN	mg TKNL	7 ± 2
Chlorides	mg Cl^{-1}/L	134 ± 56
Thermotolerant coliforms	UFC/100ml	2.131E6 ± 2.079E6

Source: Authors.

B. *Performance of the UASB reactor*

1) *Alkalinity Ratio: Intermediate Alkalinity/Partial Alkalinity*

The pH and Alkalinity indicated the stability of the anaerobic process, where the low levels of alkalinity generated a decrement of pH levels due to weak capability for neutralizing the volatile acids, as a result, occurred the accumulation of Volatile Fatty Acid (VFA) and low production of gas Methane [18]. The Alkalinity Ratio (AR) indicated the associated alkalinity to VFA and bicarbonates, where the values of AR over 0.3 suggested alterations in the anaerobic digestion. However, in particular cases, the AR values may be different to 0.3 because the nature of the wastewater, hence, is necessary to study in detail the characteristics of each process [16].

As seen in Fig. 2, the UASB reactor showed values about 1.18 ± 0.05 in the affluent and 1.27 ± 0.12 in the effluent, which evidenced instability during all the operation time. At the beginning of phase 2 was observed disequilibrium in the production and consumption of VFA because of the high acid levels, then, was necessary to modify the affluent alkalinity gradually adding sodium bicarbonate till the acid accumulation was reduced at 65-th day.

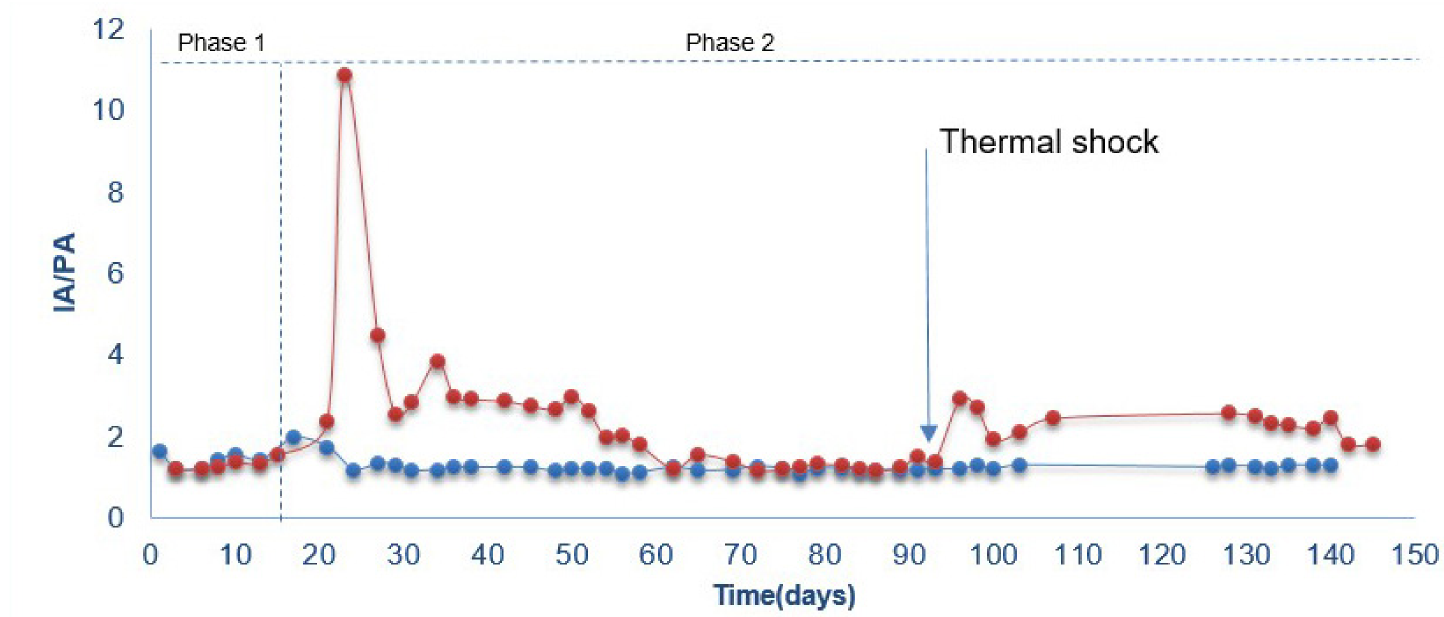

Fig. 2. Alkalinity ratio of the affluent (•) and effluent (•) derived from the UASB reactor.
IA (intermediate alkalinity), PA (partial alkalinity).
Source: Authors.

2) *VFA/ TA index*

The ratio of VFA and Total Alkalinity (TA) is known as a buffer index [16] and its proper variation considers a feasible range of 0.20-0.40 what suggested that 60% of the system's TA must be in form of Bicarbonate Alkalinity (BA) (Fig. 3). During the operation were measured mean values of 5.1.E-03 ± 3E-03 for the affluent and 0.015 ± 0.01 for the effluent, suggesting that the anaerobic process was underfed and had a low supply of nutrients.

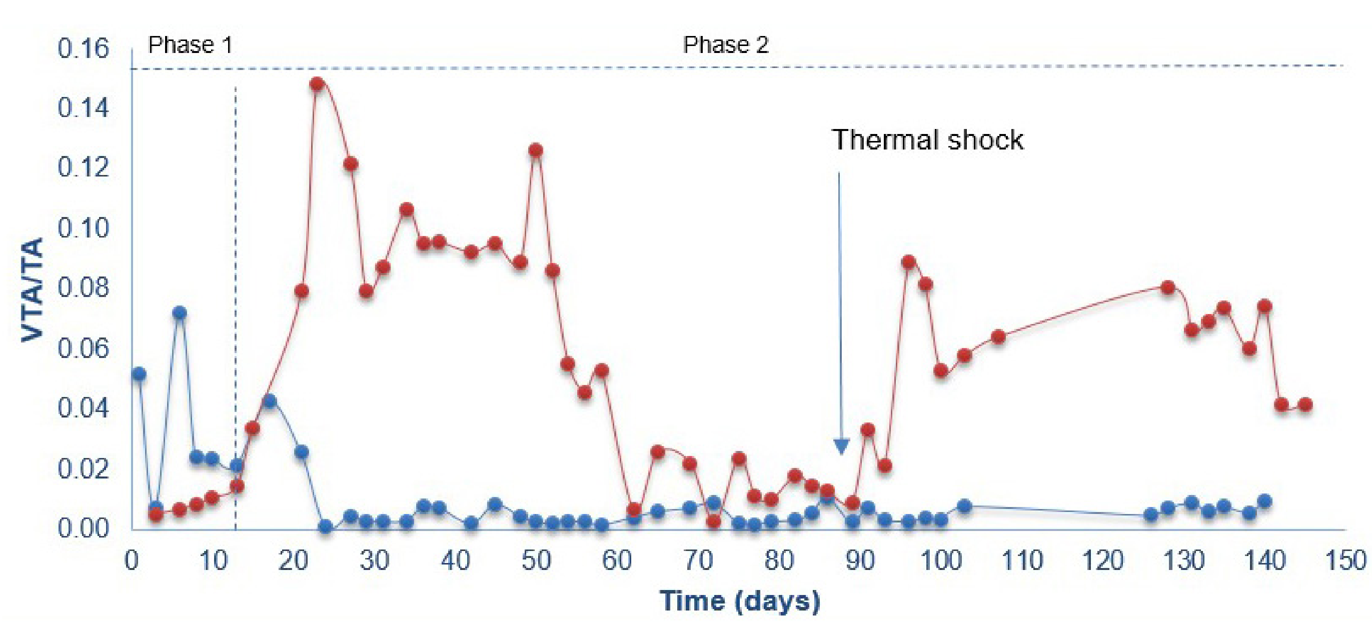

Fig. 3. Results of the VFA/ TA index for the affluent (•) and effluent (•)derived from the UASB reactor.
(VFA, volatile fatty acids, TA, total alkalinity)
Source: Authors.

The instability of the process may be caused by organic overloading, the manifestation of inhibitors agents, diluted toxics, or temperature variations; in this study, the instability occurred because the Organic Acid production of the reactor was higher than the consumption. Also, we observed that the biologic process kept under continuous perturbations and thermal shock during phase 2, as a result, the system could not recover itself. Then, the instabilities mentioned above evidenced the need to increase the research of the Hospitals' wastewater treatment through the UASB reactor, what will improve the utilization of the technology in terms of stability and efficiency.

3) *COD removal*

In Fig. 4 during the start of phase 2, a COD removal of 28% ± 20% was shown. From day number 65 the Total Alkalinity increased due to the low reactor's performance. As a result, the COD removal increased up to 59 ± 14%, what was the best result of the UASB reactor during the operation time. In this sense, the organic material reduction of hospital wastewater is dependent on the Alkalinity concentration during the treatment.

The thermal shock that occurred at day number 90 of the operation caused a critical reduction of COD removal seen in the results of 6% ± 4% (Fig. 4). Despite that situation was controlled within 24 hours and the reactor re-started at 35°C, the process could not be recovered. As a result, these kinds of wastewaters are sensitive to smoothed temperature variations during the anaerobic process. In contrast, an investigation [19] notified a thermal shock episode in a UASB reactor when treating wastewater of a bleaching plant, then, the system could recover without negative affectations for the organic material removal.

The results of some research [20] showed that a combined aerobic-anaerobic process treated hospital wastewater and reached organic material removal (COD removal) up to 95.1%. As a result, the combination of biological processes seen in that study may be an alternative for Hospitals' wastewater treatments. Also, another [12] reported similar results combining ozonation and anaerobic digestion with immobilized biomass.

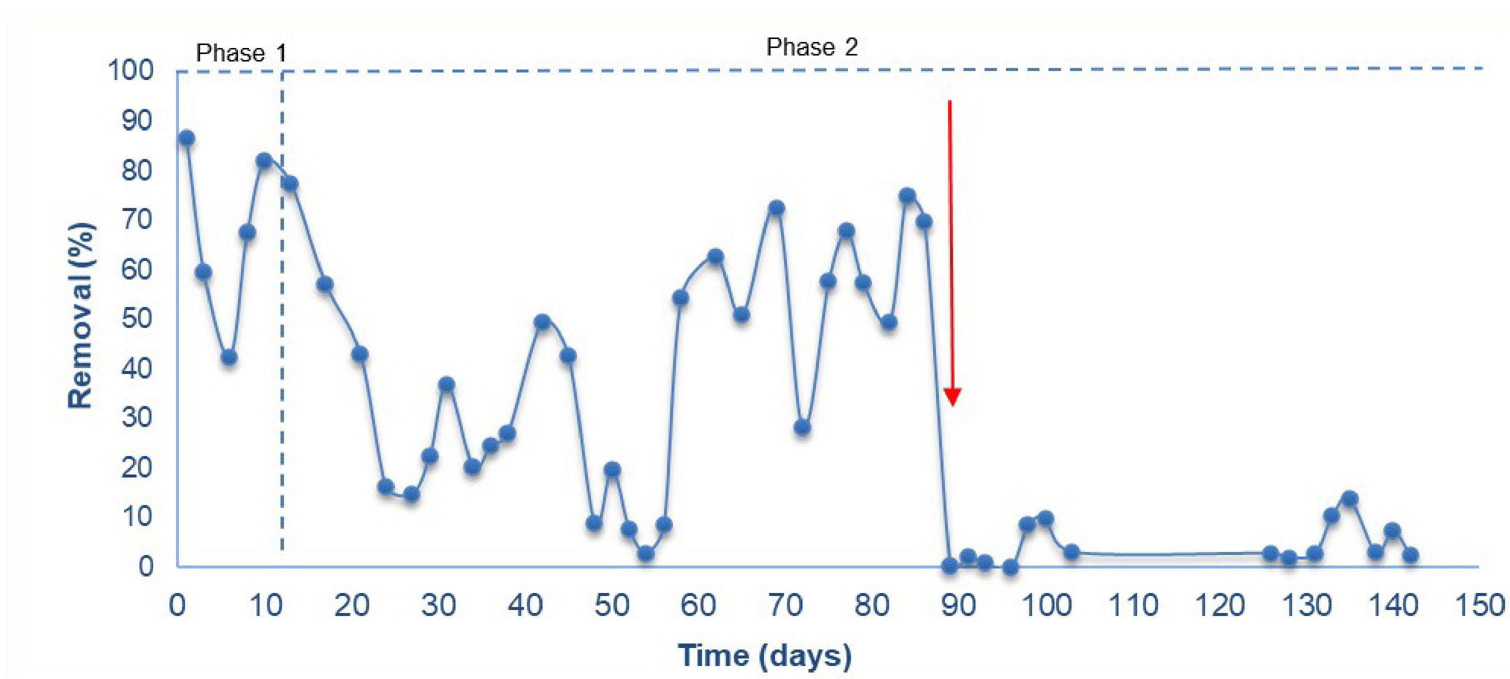

Fig. 4. COD removal percentage of the UASB reactor during the observation period.
Source: Authors.

C. *Gas Methane production*

During phase 2 at day number 90 were collected 6 samples of the biogas every 2 days, and was measured a gas Methane production of 5±1. According to certain guidelines [21], [16], the production of gas Methane was a direct result of the COD reduction, hence, in this study, the removal was not significant and the production of biogas was extremely low.

IV. Conclusions

The treatment of real Hospital wastewater through a UASB reactor was performed in this study. The results pointed out that the utilized biological reactor in the operational conditions was not effective for pollutant removal. Also, this study found that slight variations of alkalinity and temperature influenced negatively the process stability.

This study recommends studying the capability of the anaerobic biological process for treating recalcitrant compounds dissolved in the HWW. For future research would be interesting to combine the biological process with an advanced oxidation process. Finally, this research recommends performing cytotoxic and toxic measurements at different levels (ie. different bioindicators) to identify the ecotoxic impact of these wastewaters.

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References

[1] P. Verlicchi, A. Galletti, M. Petrovic & D. Barceló, "Hospital effluents as a source of emerging pollutants: An overview of micropollutants and sustainable treatment options," *J Hydrol*, vol. 389, no. 3–4, pp. 416–428, Aug. 2010. https://doi.org/10.1016/j.jhydrol.2010.06.005

[2] P. Verlicchi, M. Al Aukidy & E. Zambello, "What have we learned from worldwide experiences on the management and treatment of hospital effluent? - An overview and a discussion on perspectives," *Sci Total Environ*, vol. 514, pp. 467–491, May. 2015. https://doi.org/10.1016/j.scitotenv.2015.02.020

[3] J. B. Palter, I. Marinov, J. L. Sarmiento & N. Gruber, "Large-Scale, Persistent Nutrient Fronts of the World," *The Handbook of Environmental Chemistry*. HDB: Springer, pp. 1–38, 2006. https://doi.org/10.1007/698_2013_241

[4] P. Verlicchi, M. Al Aukidy, A. Galletti, M. Petrovic & D. Barceló, "Hospital effluent: Investigation of the concentrations and distribution of pharmaceuticals and environmental risk assessment," *Sci Total Environ*, vol. 430, pp. 109–118, Jul. 2012. https://doi.org/10.1016/j.scitotenv.2012.04.055

[5] N. A.Khan, S. U. Khan, S. Ahmed, I. H. Farooqi, M. Yousefi, A. A. Mohammadi & F. Changani, "Recent trends in disposal and treatment technologies of emerging-pollutants- A critical review," *TrAC - Trends Anal Chem*, vol. 122, 2020. https://doi.org/10.1016/j.trac.2019.115744

[6] P. Gupta, N. Mathur, P. Bhatnagar, P. Nagar & S. Srivastava, "Genotoxicity evaluation of hospital wastewaters," *Ecotoxicol Environ Saf*, vol. 72, no. 7, pp. 1925–1932, Oct. 2009. https://doi.org/10.1016/j.ecoenv.2009.05.012

[7] X.W. Wang, J. Li, T. Guo, B. Zhen, Q. Kong, B. Yi, Z. Li, N. Song, M. Jin, W. Xiao, X. zhu, C. Gu, J. Yin, W. Wei, W. Yao, C. Liu, J. Li, G. Ou, M. Wang, T. Fang, G. Wang, Y. Qiu, H. Wu, F. Chao & J. Li, "Concentration and detection of SARS coronavirus in sewage from Xiao Tang Shan hospital and the 309th Hospital of the Chinese People's Liberation Army," *Water Sci Technol*, vol. 52, no. 8, pp. 213–221, 2005. https://doi.org/10.2166/wst.2005.0266

[8] International Water Association -IWA, "Water utility managers, water professionals," in *COVID-19: A Water Professional's Perspective*. LDN, UK: IWA, 2020.

[9] S. Aydin, B. Ince & O. Ince, "Inhibitory effect of erythromycin, tetracycline and sulfamethoxazole antibiotics on anaerobic treatment of a pharmaceutical wastewater," *Water Sci Technol*, vol. 71, no. 11, pp. 1620–1628, 2015. https://doi.org/10.2166/wst.2015.126

[10] X. Shi, K. Y. Leong & H. Y. Ng, "Anaerobic treatment of pharmaceutical wastewater: A critical review," *Bioresour Technol*, vol. 245, no. Part A, pp. 1238–1244, Dec. 2017. https://doi.org/10.1016/j.biortech.2017.08.150

[11] S. Chelliapan & P. J. Sallis, "Removal of organic compound from pharmaceutical wastewater using advanced oxidation processes,," *J Sci Ind Res (India)*, vol. 72, no. 4, pp. 248–254, Apr. 2013. Available: http://hdl.handle.net/123456789/16874

[12] C. E. M. Ortiz & T. R. Chaparro, "Combination of advanced oxidation process and anaerobic process for hospital wastewater treatment," *Afinidad*, vol. 71, no. 565, pp. 63–67, 2014. Disponible en https://raco.cat/index.php/afinidad/index

[13] E. de Sousa & J.T and Foresti, "Domestic sewage treatment in an upflow anaerobic sludge blanket - sequencing batch reactor system," *Water Sci Technol*, vol. 33, no. 3, pp. 73–84, 1996. https://doi.org/10.1016/0273-1223(96)00323-X

[14] APHA (American Public Health Association), Standard Methods for examination of water and wastewater, *22 ed,* Wa, USA.: APHA, 2012.

[15] L. E. Ripley, W. C. Boyle & J. C. Converse, "Improved alkalimetric monitoring for anaerobic digestion of high-strebgth wastes," *J Water Pollut Control Fed*, vol. 58, no. 5, pp. 406–411, 1986. Available: https://www.jstor.org/stable/25042933

[16] C. Chernicharo, *Anaerobic Reactors.* LDN, UK: IWA Publishing, 2007.

[17] P. Verlicchi, M. A. Aukidy, A. Galletti, M. Petrovic & D. Barceló, "Hospital effluent: Investigation of the concentrations and distribution of pharmaceuticals and environmental risk assessment," *Sci Total Environ*, vol. 430, pp. 109–118, Jul. 15, 2012. https://doi.org/10.1016/J.SCITOTENV.2012.04.055

[18] J. S. González, A. Rivera, R. Borja & E. Sánchez, "Influence of organic volumetric loading rate, nutrient balance and alkalinity: COD ratio on the anaerobic sludge granulation of an UASB reactor treating sugar cane molasses," *Int Biodeterior Biodegradation*, vol. 41, no. 2, pp. 127–131, 1998. https://doi.org/10.1016/S0964-8305(98)00003-1

[19] A. P. Buzzine & E. C. Pires, "Cellulose pulp mill effluent treatment in an upflow anaerobic sludge blanket reactor," *Process Biochem*, vol. 38, no. 5, pp. 707–713, Dic. 2002. https://doi.org/10.1016/S0032-9592(02)00190-5

[20] A. Rezaee, M. Ansari, A. Khavanin, A. Sabzali & M. M. Aryan, "Hospital Wastewater Treatment Using an Integrated Anaerobic Aerobic Fixed Film Bioreactor," *Am J Environ Sci*, vol. 1, no. 4,pp. 259–263, Dec. 2005. https://doi.org/10.3844/ajessp.2005.259.263

[21] E. Foresti, M. Zaiat & M. Vallero, "Anaerobic processes as the core technology for sustainable domestic wastewater treatment: Consolidated applications, new trends, perspectives, and challenges," *Rev Environ Sci Biotechnol*, vol. 5, no. 1, pp. 3–19, Feb. 2006. https://doi.org/10.1007/s11157-005-4630-9

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