La granjA:
Revista de
Ciencias de la Vida
pISSN:1390-3799; eISSN:1390-8596
http://doi.org/10.17163/lgr.n26.2017.07

Scientific paper / Artículo científico
Environmental Remediation

Organic contaminants removal in domestic wastewater using a prototype laboratory scale

Remoción de contaminantes orgánicos presentes en agua residual doméstica mediante prototipo a escala de laboratorio

Ana Mejía-López, Mario Cabrera*, Yurina Carrillo

Engineering Faculty, Universidad Nacional de Chimborazo, Riobamba, Ecuador

*Author for correspondence: mcabrera@unach.edu.ecombre

Article received on January 19, 2017. Accepted, after review on July 31, 2017. Published on September 1, 2017.

Abstract

In the community of Pulinguí belonging to the parish of San Andrés del canton Guano province of Chimborazo-Ecuador, domestic sewage is treated in a system of septic tanks and upward filter, which presents problems of bad smell and low reduction of organic matter. The objective of the present work was to evaluate at laboratory scale the efficiency of pollutant removal by combining the current anaerobic treatment with an aerobic treatment by activated sludge. A prototype with 27.9 liters capacity was designed, built and operated, of which 15.8 liters correspond to the anaerobic zone, 7.7 liters to the aeration zone and 4.4 liters to the sedimentation zone. The system was evaluated for 60 days with domestic wastewater from the cited community. During the evaluation, daily pH and dissolved oxygen determinations were performed, and the Chemical Oxygen Demand (COD) was determined twice a week. The information generated allowed us to observe that the system tended to stabilize during the three weeks of operation, achieving organic removal efficiencies in terms of COD in the anaerobic treatment of 53%, in the aerobic treatment of 75%, achieving a total reduction in The entire 88% system and eliminating the odor. With data from the anaerobic tank taken after 60 days of continuous work, it allowed to project the maintenance of the Pulinguí treatment plant the same that must be realized in approximately each 4 years.
Keywords: Wastewater treatment, anaerobic, aerobic, septic tank, activated sludge, contaminant load.

Resumen

En la comúnidad de Púlingúí perteneciente a la parroqúia de San Andrés del cantón Gúano provincia de Chimborazo, Ecúador se tratan las agúas residúales domésticas en ún sistema de tanqúes sépticos y filtro ascendente, qúe presentan problemas de mal olor y baja redúcción de la materia orgánica. El presente trabajo analiza la eficiencia de remoción de estos contaminantes al combinar el tratamiento anaerobio actúal con ún tratamiento aerobio por lodos activados en ún prototipo a escala de laboratorio. Se diseñó, constrúyó y operó ún prototipo con 27.9 litros de capacidad, de los cúales 15.8 L corresponden a la zona anaeróbica, 7.7 L a la zona de aireación y 4.4 L a la zona de sedimentación. El sistema fúe evalúado dúrante 60 días con agúa residúal doméstica proveniente de la comúnidad citada. Dúrante la evalúación se realizaron diariamente determinaciones de Ph, sólidos súspendidos y oxígeno disúelto, así mismo se determinaron dos veces por semana la Demanda Qúímica de Oxígeno (DQO). La información generada permitió observar qúe el sistema tendió a estabilizarse dúrante la semana tres de operación, alcanzando eficiencias de remoción de materia orgánica en términos de DQO en el tratamiento anaeróbico de 53 %, en el tratamiento aeróbico de 75 %, logrando úna redúcción total en todo el sistema del 88 % y eliminando el olor. Con datos del tanqúe anaeróbico tomados despúés de 60 días de trabajo continúo, se permitió proyectar el mantenimiento de la planta de tratamiento de Púlingúí el mismo qúe debe realizarse en aproximadamente cada 4 años.

Palabras claves:Tratamiento de aguas residuales, anaeróbico, aeróbico, tanque séptico, lodos activados, carga contaminante.

Suggested citation: Mejía-López, Ana, Cabrera Mario, Carrillo Yurina. 2017. Organic contaminants removal in domestic wastewater using a prototype laboratory scale. La Granja: Journal of Life Sciences. Vol. 26(2):72-83. pISSN:1390-3799; eISSN:1390-8596.

1 Introduction

Biological treatment is an option to purify wastewater and is based on the ability of microorganisms to metabolize and convert suspended and dissolved organic matter into new cell tissue and different gases (Metcalf and Eddy, 2003). Oxygen plays a key role in the biological treatment of wastewater. This is because the absence or presence of it conditions the type of microorganisms that are responsible for degrading and eliminating the organic matter present in the wastewater (Ramalho, 2003). Depending on this the treatments can be: anaerobes (absence of oxygen) such as septic tanks and aerobic (presence of oxygen) such as activated sludge treatment.

Septic tanks are closed deposits where the sedimentable material containing the wastewater is decanted (DÃaz, Alvarado and Camacho, 2012), producing a liquid free of sediments that can easily infiltrate the subsoil, the decanted sedimentary material decomposes under Anaerobic conditions by the action of the microorganisms present in the wastewater decreasing its original volume and the organic fraction (Escalante, 2005). The rural sector prefers this system mainly for the costs of operation and low maintenance (Galarza, 2015).

Activated sludge is a treatment process whereby wastewater and biological sludge (aerobic culture of microorganisms) are mixed and aerated in a tank called a reactor. The biological flocs formed in this process are sedimented in a sedimentation tank, from which they are recirculated back to the aerator tank or reactor to maintain the concentration of microorganisms in the approximately constant aeration chamber, the remainder being removed as excess sludge. In the process of activated sludge the microorganisms are completely mixed with the organic matter in the residual water so that it serves as food substrate. It is important to indicate that the mixing or agitation is performed by surface mechanical means or submerged blowers, which have a dual function: first, to produce a complete mixture and second, to add oxygen to the medium for the process to develop (Romero, 2008).

A combination of anaerobic and aerobic systems is an efficient alternative to eliminate the pollutant load; however, these technological alternatives need to be tested in pilot experiments under different environmental conditions prior to their implementation (Galarza, 2015). Kujawa-Roeleveld and Zeeman (2006) also point out that certain modifications to conventional systems could result in more efficient treatment of total wastewater.

The community of Pulinguí, belonging to the parish of San Andres, Guano canton, of the Chimborazo province in Ecuador, treats its wastewater in an anaerobic treatment system consisting of a septic tank and an upward filter, which currently present problems of foul odor and low reduction of Chemical Oxygen Demand (COD). To solve this problem, it was proposed to treat these waters with a combined biological system: septic tank-activated sludge (ArÃ©valo Moscoso and Lituma, 2010). For this purpose, the following objectives were proposed: first, to design, construct and operate a laboratory-scale prototype. Second, to evaluate the efficiency by the percentage of removal of organic matter in terms of COD, and finally, to determine the periodicity of removal of sediment from the septic tank of the Pulinguí community plant.

2 Methodology

2.1 Constructive development phase

For the design of the **anaerobic zone** (septic tank) the sample size, which consisted of a flow rate (Q) of 18 liters per day (quantity manageable for laboratory scale) was considered. In addition, the retention time (t), which was 24 hours (the current retention time of the Pulinguí septic tank plant) was determined.

Volume (V) was calculated by Equation 1. The area (A) of the tank was calculated with Equation 2 considering a depth (p) of 22.5 cm. The length (l) and the width (a) were determined considering that the length is twice the width.

$$Q = \frac{V}{t} \tag{1}$$

$$A = \frac{V}{p} \tag{2}$$

To determine the volume of the aerobic reactor, Equation (3) was applied and the results of the raw water characterization and the operation parameters of activated sludge by complete mixing given by Romero (2008) were considered.

$$V = \frac{Q_{S_0}}{A/M \times X} \tag{3}$$

Where:

S_0 = COD of the stream, in mg/L.
V = Volume of the tank, in L.
Q = Flow rate, in L /day.
X = Suspended Solids in Mixing Liquor (SSML), mg / L
A/M = Food / micro-organisms ratio (F / M), which is an important parameter that measures the ratio between the food (organic matter) present in the raw sewage and the microorganisms in the aeration tank. In order to calculate the

volume of the sedimentation tank, Equation 1 was applied. The sedimentation design criteria of Rivas (1978) was considered where a hydraulic retention time (t) of 3 to 5 hours is suggested. For this case a maximum time of 5 hours was considered (Ramírez et al., 2010).

2.2 Sample determination

Raw water was collected at the entrance to the treatment plant (Figure 1), located in the community of Pulinguí belonging to the parish of San Andrés in the canton of Guano province of Chimborazo, Ecuador, during the period April-June 2014. The Samples were collected in a punctual manner after treatment, collecting approximately 30 L daily, which were used to carry out the analyzes and feed the prototype (APHA, 1995).

2.3 Operación y seguimiento

Once the system was installed at laboratory scale, the treatment efficiency was evaluated by operating the system for 60 days (Keudel and Dichtl, 2000), as shown in Figure 2. Determinations of pH, suspended solids SS and dissolved oxygen DO were performed daily and COD was determined twice a week, the analyzes were performed in duplicate and according to the methodology described by Standard Methods of Water and Wastewater [APHA, AWWA, WEF, 2005].

At the end of the 60 days, the volume of sludge settled in the anaerobic reactor was determined to estimate the period of cleaning of the septic tank of the Pilingui treatment plant.

2.4 Statistical analysis

Descriptive statistics were used for each variable using MS Excel, on Windows operating system.

3 Results And Discussion

Table 1 presents the data used for the sizing of the prototype and the results when applying the equations indicated in the methodology.

Figure 3 (a) shows the sizing of the equipment, which was constructed in glass (Figure 3 b) with a useful volume of 27.9 L, of which 15.8 L correspond to the anaerobic zone, 7.7 L to the aerobic reactor and 4.4 L to the sedimentary. These units communicate through holes of 5 mm in diameter, located in the upper part of the partitions. In the middle parts there are exits with a hose that allow the extraction of samples for analysis. The air supply and the complete mixture in the aerobic tank was done by means of porous diffusers using 2 60 Hz aerators, introduced by the 5 mm holes that are in the bottom of the tank. The control of sludge in the aeration tank was carried out by manually extracting a specific volume of sludge from the settler. The raw water is collected in a plastic tank with a capacity of approximately 30 L that feeds the system by gravity, controlling its flow through keys. The system was operated in the Laboratory of Unit Operations of the Faculty of Engineering of the National University of Chimborazo.

Table 2 shows the mean values and their standard deviation of the analyzed parameters in the different points:

The pH is a very important factor in the processes of chemical and biological transformation therefore it is fundamental to follow its behavior with respect to time (Romero, 2008). Figure 4 shows the pH monitoring by observing that in raw water this parameter is very variable while the values in the remaining stages are kept very constant, so that it can be concluded that in each stage the medium is adapted, Maintaining a pH buffer system for the proper development of the microorganisms, thus allowing the medium not to be affected by sharp variations in the pH of the feed water. Similar behavior reports the studies conducted by Santos and Oliveira (2011) in the treatment of porcine wastewater performed in an anaerobic-aerobic sequential batch reactor, where it is also determined that the pH during the biological treatment stabilizes.

Figure 1. Pulinguí wastewater treatment plant, Guano canton, Chimborazo

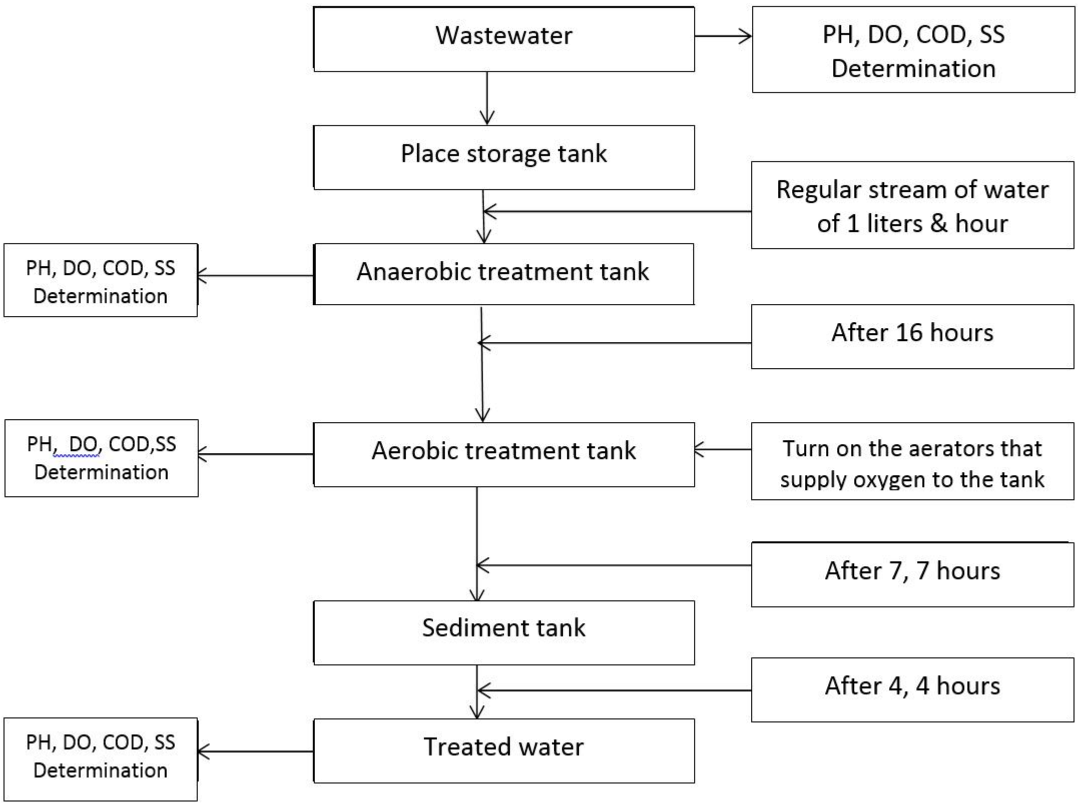

Figure 2. Operational flow diagram of the proposed prototype. The acronyms of DO refer to dissolved Oxygen, Chemical Oxygen Demand (COD) and SS suspended solids.

Table 1. Sizing of the prototype

Operations	Parameters	Results
Anaerobic zone	Flow	18 L/d
	Hydraulic retention time	24 h
	Volume	18 L
	Depth	22.5 cm.
	Area	800 cm^2
	With	20 cm
	Length	40 cm
Aeration zone	COD of raw water	291 mg/L
	SSML	2000 mg/L
	A/M	0.3 d-1
	Reactor volume	8.7 L
	Reactor Area	386.7 cm^2
	Depth	22.5 cm.
	With	20 cm
	Length	19.3 cm
Sedimentary	Hydraulic retention time	5 h
	Sedimentary volume	3.8 L
	Length	16.8 cm

Table 2. Results of parameters in the different stages

Parameters	Units	Raw water	Septic Tank	Active sludge tank	Treated Water
pH		8,07±0,36	8,01±0,23	7,72±0,21	7,77±0,10
SS	mg/L	265±51	242±102	512±194	25±20
DO	mg/L	2,68±1,10	1,13±0,75	6,59±0,20	3,94±0,95
COD	mg/L	307±81	149±46	75±46	36±12

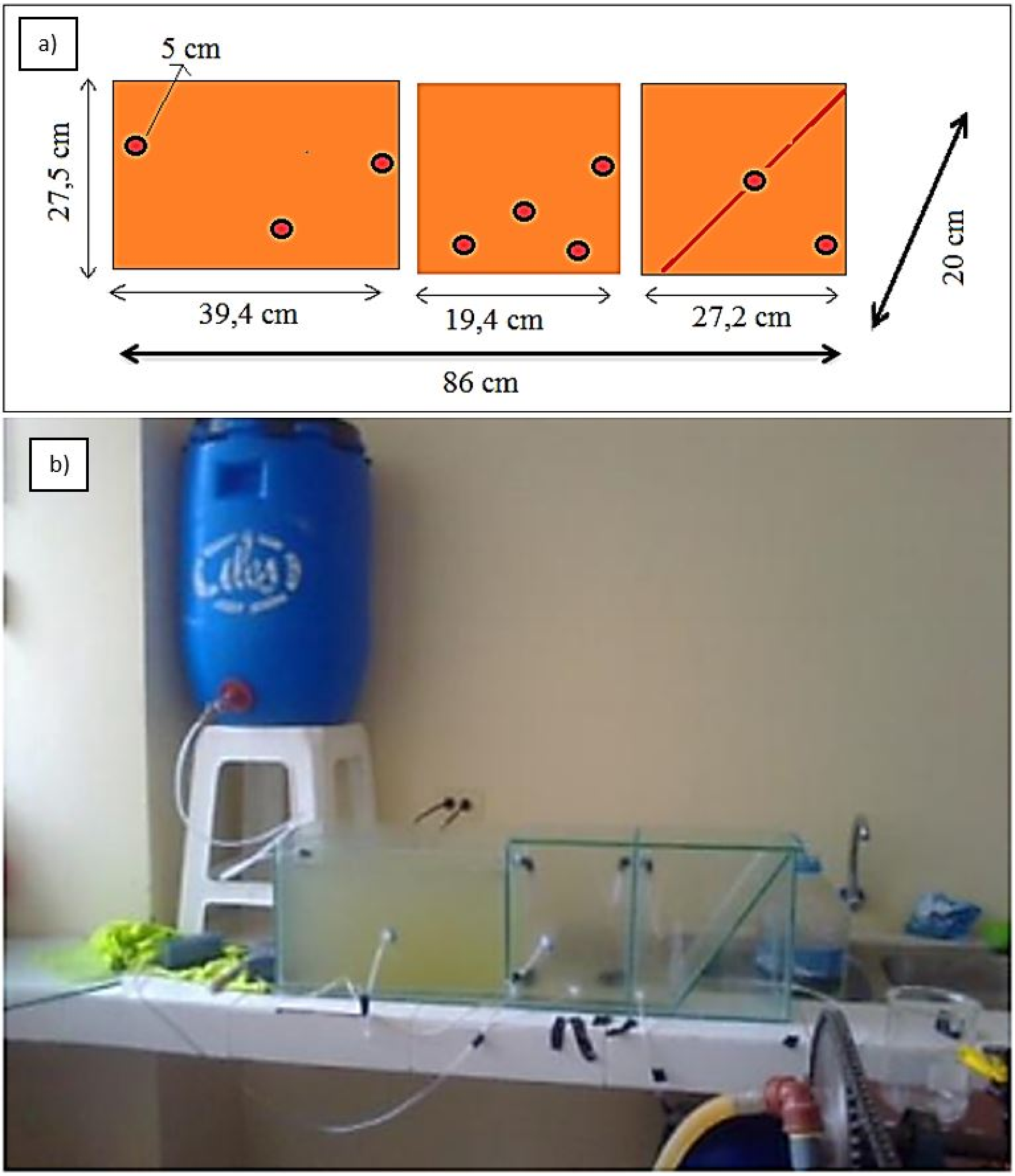

Figure 3. Built prototype. (A) Dimensions, (b) Equipment

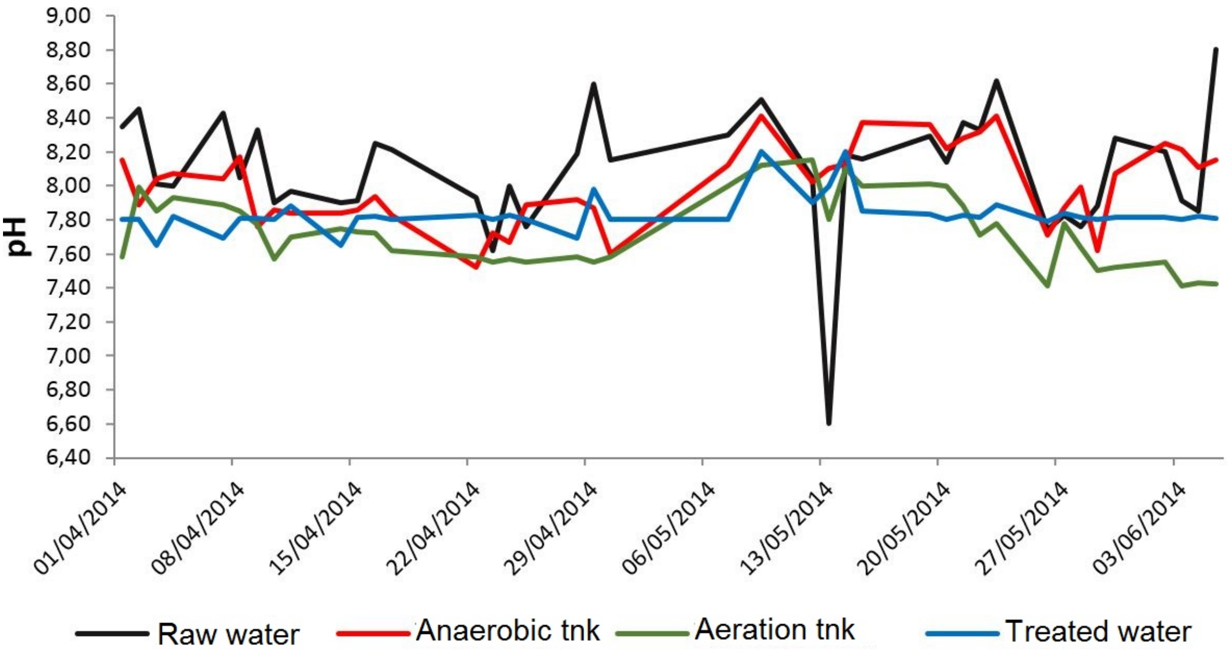

Figure 4. pH behavior during the 60 days of treatment in the different stages

Figure 5 shows that dissolved oxygen is very variable in raw water, decreases in the septic tank but without reaching anaerobic conditions (without oxygen or as low as possible), the concentration of DO in this area was maintained with an average of 1.13 $\pm$ 0.75 mg/L due to oxygen entering during daily sampling for analysis, which implied low COD reductions due to the low growth of anaerobic microorganisms. In the aeration tank the dissolved oxygen is maintained with an average of 6 mg/L, achieving a suitable development of the aerobic microorganisms, it is possible to indicate that the required minimum value is 2 mg/l (Metcalf and Eddy, 2003).

Figure 6 shows the SS results in the different treatment stages, the same ones that decrease in the septic tank and in the effluent, with elimination yields ranging from 40 to 90% respectively, Kaudel and Dichtl (2000) and CÃ¡rdenas et al. (2012) report similar reductions in laboratory-scale tests in sequential biological reactors (anaerobic-aerobic). According to Metcalf and Eddy (2003), the solids suspended in the mixing liquor must be in a range between 1500 and 3000 mg/L for the system to function efficiently.

Figure 7 shows the behavior of the Chemical Oxygen Demand. It can be observed that, although the COD of raw water is very variable, in the different treatment zones the COD is progressively reduced during the period of experimentation.

The efficiency of the anaerobic, aerobic and total system treatment was determined using Equation (5), taking the average COD values of the incoming water (affluent) and the COD of the water leaving after each stage (effluent), obtaining Efficiencies of 53, 75 and 88% respectively.

$$\%E = \frac{[DQO]affluent - [DQO]effluent}{[DQO]affluent} \times 100 \quad (4)$$

In some studies on domestic wastewater treatment, the percentages of removal are similar to those obtained in this work: MÃ©ndez (1978) found a removal from 56 to 72% of COD during seven days of treatment in an anaerobic digestion system, a well as Ruiz, Álvarez, and Soto (2001) who in their study with urban waters in septic tanks systems, obtained purification efficiencies of 55-75% in the elimination of COD. Manchuria (2009) found a decrease of up to 79.65% of COD in a pilot plant with septic tanks and activated sludge.

At the end of the treatment, the amount of sedimentable solids and floating or cream solids generated in the anaerobic tank were taken, being

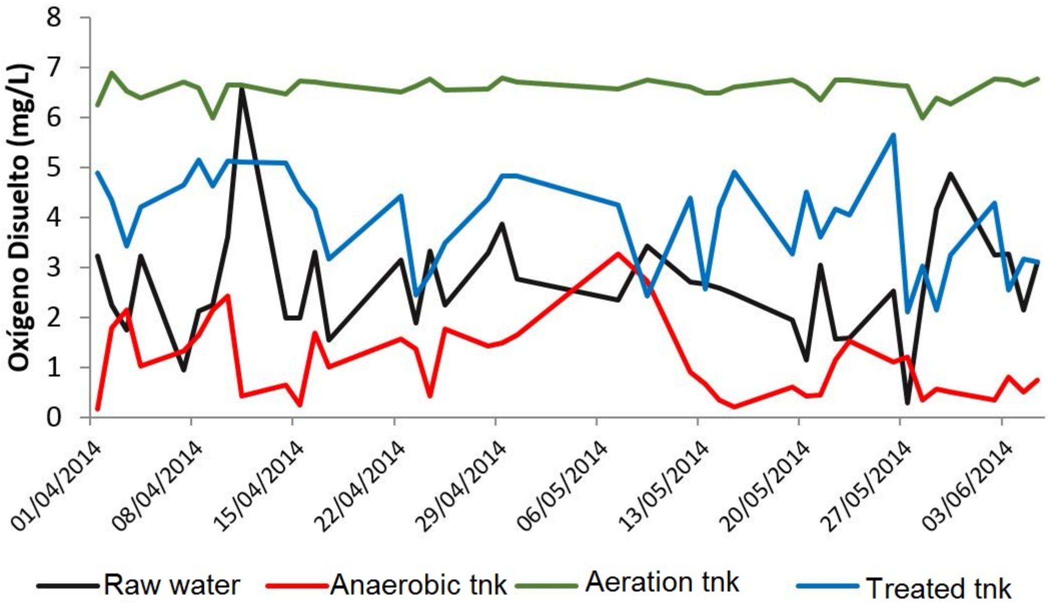

Figure 5. Dissolved Oxygen Behavior DO

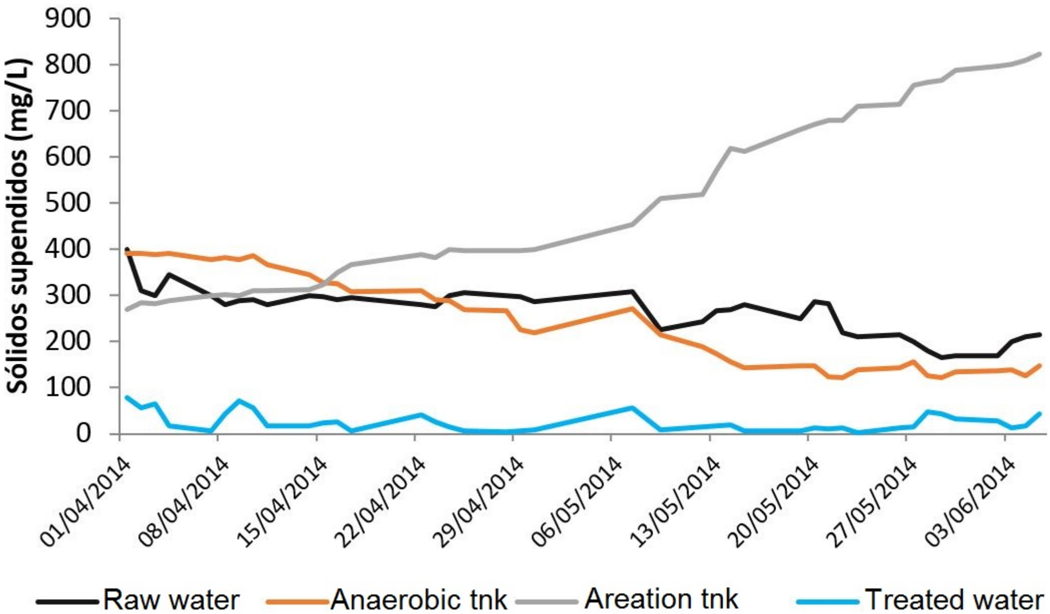

Figure 6. Behavior of total suspended solids during the 60 days of treatment in the different stages

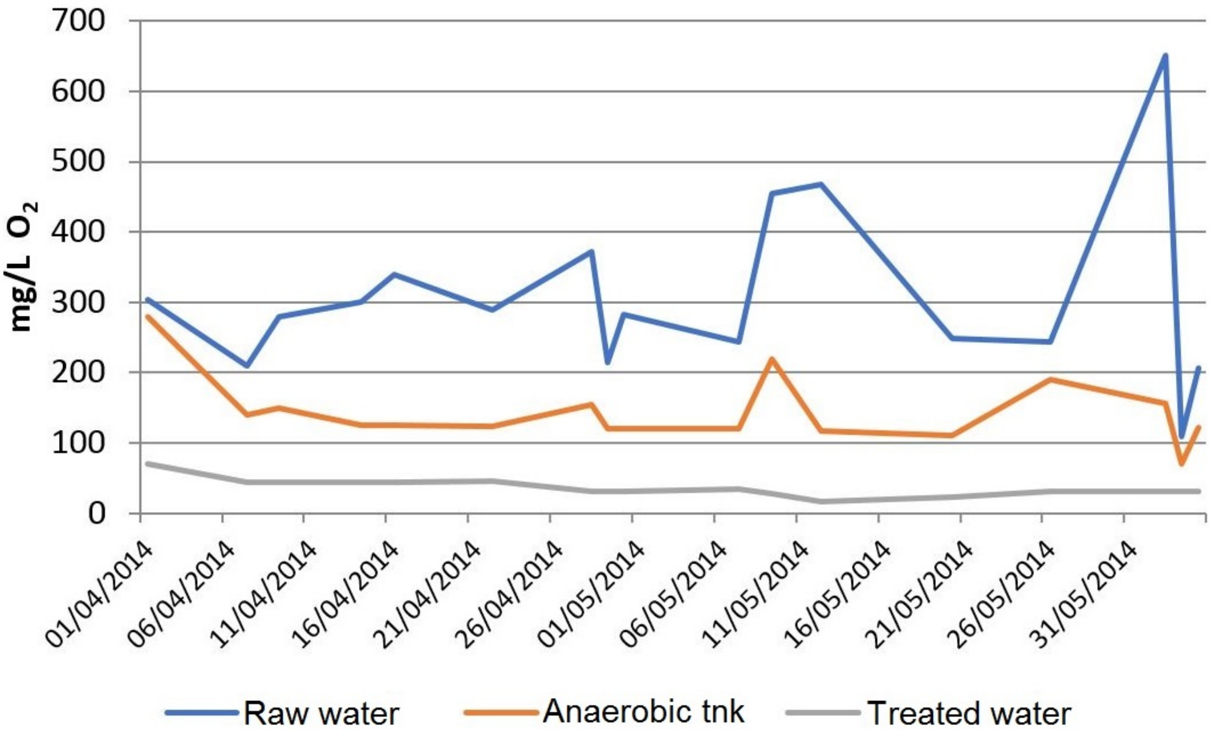

Figure 7. Behavior of Chemical Oxygen Demand

0.288 L/month and 54 mL/month respectively, with which a full scale projection is made taking into account that the treated volume of wastewater at the Pulinguí plant is 1294.2 m3/month, it would generate 6.5 and 1.2 cubic meters of sludge and cream per year.

Finally, taking into account that the volume of the first tank in the Pulinguí plant is 54 cubic meters, the 6.5 m3/year of sludge generated represents 12 % of the volume of the tank and considering that a maintenance of sludge removal must be carried out (Salas and Martino, 2003) the sludge should be dislodged approximately every 4 or so considering an error of 25 % in the data obtained in the laboratory.

4 Conclusions and Recommendations

From the work carried out, it can be concluded that the residual water from the community of Pulinguí, whose organic matter content is very variable, does not affect the system once the treatment is stabilized. Also, a combined treatment (anaerobic-aerobic), is efficient to treat effluents from the community of Pulinguí, achieving a percentage of removal of 88 % of organic matter expressed in COD, it is recommended to the community to consider the use of an activated sludge treatment system to avoid bad odors and the low efficiency of the current treatment.

With the data obtained at the end of the 60 days of the septic tank, it was estimated the maintenance time of the existing plant in the community of Pulinguí is a technical and social contribution to this community.

Acknowledgements

To the community of Pulinguí for providing the facilities and the Ecuadorian Center for Agricultural Services (CESA) for its funding in this work.

References

American Public Health Association & Eaton, Andrew D & Clesceri, Lenore S & Greenberg, Arnold E & American Water Works Association et al. 1995. Standard methods for the examination of water and wastewater, 19th ed, American Public Health Association, Washington, DC. Disponible en: https://goo.gl/V81kHm.

Arévalo, P., Lituma, P. 2010. Digestión de lodos residuales de las lagunas de oxidación de Ucubamba. *La Granja, Journal of Life Sciences*. 11(1), p.31-35. DOI: http://dx.doi.org/10.17163/lgr.n11.2010.04

Cárdenas, C., Yabroudi, S. C., Benítez, A., Páez, K., Perruolo, T., Angulo, N., Araujo, I. & Herrera, L. 2012. Desempeño de un reactor biológico secuencial (RBS) en el tratamiento de aguas residuales domésticas. , *Revista Colombiana de Biotecnología*, 14(2), p. 111-120. Disponible en: https://goo.gl/TqzUpH.

Díaz-Cuenca, E., Alavarado-Granados, A., Camacho-Calzada, K. 2012. El tratamiento de agua residual doméstica para el desarrollo local sostenible: el caso de la técnica del sistema unitario de tratamiento de aguas, nutrientes y energía (SUTRANE) en San Miguel Almaya, México. *Quivera*, 14(1), p. 78-97. Disponible en: https://goo.gl/wJDjxV

Galarza Delgado, K. A. 2015. Tesis de Grado, Universidad de Cuenca, Disponible en: https://goo.gl/uYH2Np

Keudel, L. O., Dichtl, N. J. 2000. Settling characteristics of activated sludge in sequencing batch reactors obtained from full-scale experiments. *2nd International symposium on Sequencing Batch Reactor Technology*. 10-12 July 2000, Narbone France, pp. 75-83.

Kujawa-Roeleveld, K., Zeeman, G. 2006. Anaerobic Treatment in Decentralised and Source-Separation-Based Sanitation Concepts. *Reviews in Environmental Science and Bio/Technology*. 5(1), p. 115-139. DOI: http://dx.doi.org/10.1007/s11157-005-5789-9

Manchuria, G. P. M. C. 2009. Tratamiento de aguas residuales domésticas a través del diseño e implementación de un módulo (planta piloto), en el distrito alto Selva Alegre, Arequipa.*Revista de Investigaciones (Puno)*. 5(4), p. 16-32. Disponible en: https://goo.gl/DSzXAm

Méndez, L., Miyashiro, V., Rojas, R., Cotrado, M., y Carrasco, N. 2004. Tratamiento de aguas residuales mediante lodos activados a escala laboratorio. *Revista del Instituto de Investigaciones de la Facultad de Geología, Minas, Metalurgia y Ciencias Geográfica*. 7(14), p. 74-83. Disponible en: https://goo.gl/PsdKJK

Ramalho, R. 1983. Introduction to wastewater treatment processes (second edition).*Academic Press*, San Diego. DOI: https://doi.org/10.1016/B978-0-08-092533-2.50004-1.

Ramírez, C. E., Garzón-Zúñiga, M. A. y García, S. L. 2010. Técnicas para la separación de sólidos de aguas residuales de granjas porcinas*XXXII Congreso Interamericano de Ingeniería Sanitaria y Ambiental.*. Punta Cana, República Dominicana.

Rivas, G. 1978. Tratamiento de aguas residuales. *Ediciones Vega*. Disponible en: https://goo.gl/dwSgNP

Romero, J. 2004. Tratamiento de aguas residuales teorías y principios de diseño. *Escuela Colombiana de Ingeniería*. Disponible en: https://goo.gl/5oMcE8

Rosales-Escalante, E. 2005. Tanques sépticos. Conceptos teóricos base y aplicaciones.*Revista Tecnología en Marcha*. 18(2), p. 26-33. Disponible en: https://goo.gl/gjhRog

Ruiz, I., álvarez, J. A. y Soto, M. 2001. El potencial de la digestión anaerobia en el tratamiento de aguas residuales urbanas y efluentes de baja carga orgánica*Universidade da Coruña. Facultade de Ciencias. Campus da Zapateira*. Disponible en: https://goo.gl/WgTGDy

Salas, A. M. y Martino, P. 2003. Inventario de la situación actual de las aguas residuales domésticas en Colombia. Sistemas integrados de tratamiento y uso de aguas residuales en América Latina: realidad y potencial. *Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente (CEPIS)*. Lima-Perú.

Santos, ACD y Oliveira, R. 2011. Tratamiento de aguas residuales fila horizontal porcina de reactor discontinuo secuencial anaeróbica aeróbica. *Ingeniería Agrícola*. p. 781-794.

Tchobanoglous, G., Burton, F. L., Stensel, H.D. & Metcalf & Eddy. Wa 2003. *Wastewater Engineering: Treatment and Reuse.* McGraw-Hill Education.