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Removal of Organic Pollutants from *San Pablo* Farm Wastewater Using a Pilot-Scale Biological Treatment

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Abstract

Biological treatment is the most common process used to treat organics-containing wastewaters from industrial, domestic and agricultural activities. This work aims to remove organic pollutants using pilot-scale biological treatment system based on activated sludge. In addition, physical, chemical and microbiological characteristics of *San Pablo* Farm wastewaters were determined through analyses such as COD, DO, VSS, TSS and BOD and kinetic parameters were calculated by monod model. It was observed a significant decrease of this contaminant load in wastewater, achieving removal yields of 98% of BOD, 93% of COD and 99% of total coliforms. Kinetic coefficients obtained at pilot-scale registered similar values to those described by other researches and reveal a good performance of activated sludge in wastewater treatment.

Keywords: Wastewater, activated sludge, kinetic parameters, biological treatment

1 Introduction

Currently, increasing economic development and human population have caused contamination of water sources by substances such as agricultural chemicals, detergents, and pharmaceuticals [1], which decrease quality of water and generate negative consequences for existing ecosystems [2, 3]. In fact, agricultural activities contribute significantly to this environmental problem [4]. Decontamination of water is a major concern and technologies such as chemical precipitation, membrane filtration, biological processes, biosorption and adsorption can be used for decontamination of effluents [5]. Biological treatment of wastewaters is usually applied for many urban or industrial wastewaters in the field of food, fermentation, papermaking, and so on [6]. These processes have the advantage of being more economic and environmentally friendly, using optimized natural pathways to actually destroy pollution, not only transform it into another form [7]. One of the most implemented biological systems are activated sludge due to its high efficiency [8], reaching removal yields in BOD, COD and SSV up to 95% , 80% and 95% respectively [9]. This project presents a detailed study based on analyzing the physicochemical and microbiological composition of wastewater from *San Pablo* farm belonging to *Francisco de Paula Santander* University, which are being discharged directly to the *El Volcán* and *Ribiquí* brook without previous treatment. In addition, a pilot-scale wastewater treatment of activated sludge was applied in order to remove pollutants from wastewater and guarantee environmental conditions of aquatic ecosystems under Colombian regulations.

2 Materials and Methods

2.1. Quantification of crude sewage

Crude sewage was obtained from fish farming activity, washing of stables and domestic activities, which was monitored during 6 months, depending on the moment of discharging. The method for flow measuring was carried out volumetrically with a calibrated vessel. The flow rate was calculated by averaging flows previously quantified in monitoring.

2.2 Physical-chemical and microbiological characterization

Physical-chemical and microbiological analyzes were carried out on samples of crude sewage from farm and in the effluent of reactor, sedimentation tank and activated sludge lagoon of pilot plant. These analyses corresponded to chemical oxygen demand (COD), nitrates, inorganic phosphorous, dissolved oxygen (DO), volatile suspended solids (VSS), total suspended solids (TSS), salinity, conductivity, biochemical oxygen demand (BOD), total and fecal coliforms, acidity, alkalinity and water hardness using spectrophotometry, brucine method, modified method of Taussky and Shorr, colorimetric, gravimetric, potentiometric, respirometric, membrane filtration and volumetric techniques.

2.3 Activation of sludge and pilot system operation for biological treatment: The activation of sludge was carried out with a mixture of wastewater from washing of stables and fishponds and enough oxygen (2 to 4ppm) as is shown in Table 1.

Table 1. Mixture for sludge activation

Time (days)	Crude sewage from stables washing (%)	Crude sewage fishponds (%)
1	20	80
3	40	60
5	50	50
7	70	30
11	100	0

2.4 Pilot –scale system operation

The operation consisted of a standard activated sludge treatment with an aerated and agitated reactor, followed by settlement tank including sludge recirculation and lagoon. An inlet flow of 1.17 L/h was fixed, with a reactor functional volume of 20 L and a retention time of 17 h; complete mixing was maintained through aeration through airflow of 1.2 vvm and maintaining dissolved oxygen concentration of 2 mg/L. The reactor, settlement tank and lagoon were monitored every 24 hours and analysis of COD, SSV, nitrates and inorganic phosphorus were performed. The OD, pH and temperature values provided by reactor sensors were also reported.

2.5 Determination of kinetic parameters

Monod model and activated sludge kinetic model [10] were used to determine kinetic parameters of Equation (1).

$$\frac{X\theta}{So - S} = \frac{Ks}{K} * \frac{1}{S} + \frac{1}{K} \quad (1)$$

3 Results and Discussion

3.1 Physicochemical and microbiological characterization

The physical-chemical characteristics of wastewater correspond to 382 mg/L ± 50,92 BOD; 696,481 mg/L ± 158,111 COD; 462 mg/L ± 8.2 SSV; 36.95 mg/L ± 6.521 inorganic phosphorus; 82.1 mg/L ± 1.1 nitrates; 9.5 ± 4.324 x107 CFU / 100ml of total coliforms. These results suggested that organic load of *San Pablo* farm is high and requires a biological treatment system.

3.2 Sludge activation

Figure 1 shows sludge activation beginning with aeration process, where a brown-mixed liquor containing low amount of foam is identified (Figure 1.B). At microscopic level, sludge structure is showed (Figure 1.A), where organic matter and saprobic organisms of order *Amoebida* and *Dinoflegelados* were observed, which are characteristic at high concentrations of organic matter and precarious oxygen conditions (0.2 - 1 mg/L OD), common in low times of cellular retention (0.2 - 1 days). Figure 1.C shows the appearance of bacteria and some ciliates, both fixed (*Vorticella*) and free (*Paremicium*). Figure 1.D shows the optimal zone for activated sludge, predominant microorganisms are free ciliates and bacteria, both subsist with a medium - low amount of substrate.

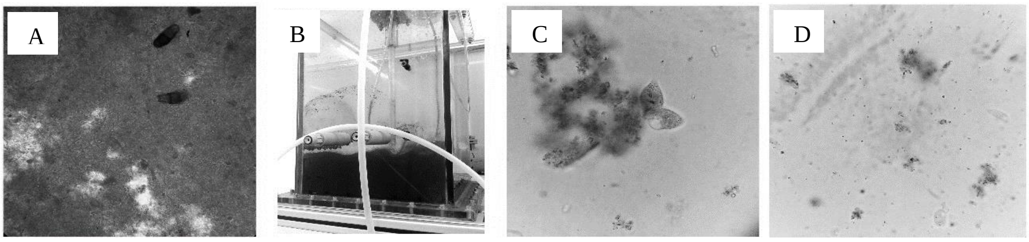

Figure 1. Sludge activation process

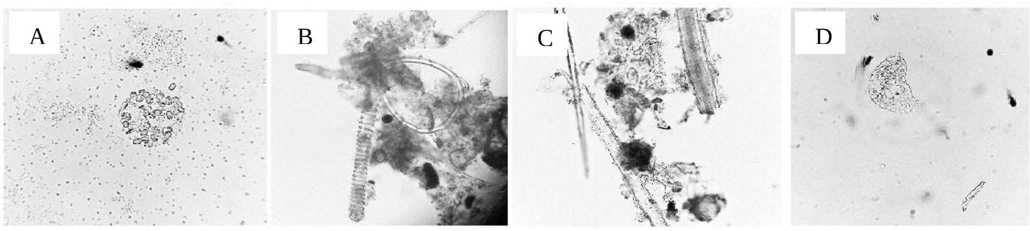

Figure 2. Activated sludge micrographs

The composition of activated sludge obtained in this work demonstrates a complex association of microorganisms that are responsible of carrying out the process of degradation and transformation of matter from *San Pablo* farm wastewater (Figure 2). It was found that microorganisms in activated sludge are corresponded to bacteria (Figure 2. A), protozoa (Figure 2.B), fungi (Figure 2. C), ciliates (Figure 2. D). The presence of these organisms in activated sludge is associated with the different concentrations of nutrients and organic matter present in wastewater, which play an important role in the development and maturation of activated sludge. The available substrate, cellular retention time and wastewater flow are important parameters for sludge activation, which allow determining optimal conditions for crude sewage treatment and proliferation of biotic structure, since these microorganisms do not grow freely, but they appear in flocs that allow to protect themselves of external agents or environmental conditions. Other authors [11] reported microorganisms in the active sludge of slaughterhouse wastewater similar to those found in this work.

3.3. Pilot plant operation

Table 2 summarizes the parameters quantified at the end of the treatment. After treatment, a removal yield of 98.04% of BOD, 92.99% of COD and 99.73% of the total coliforms were obtained.

Table 2. Initial and final parameters and removal yields

Parameter	Units	Inlet	Reactor	Settlement tank	Lagoon	%Removal yield
Flow	L/s			$3.25x10^{-4}$		N/A
Sludge recycle	L/h			2		N/A
Functional volume	L		20.28	30	170	N/A
Retention time	h		17.34	25,64	145,75	N/A
Hydrogen potential	pH	8.066±0.277	8.55±0.09	N.R.	N.R.	N/A
Water temperature	°C	22.22±1.96	28.74±0.71	31±0.73	N.R.	N/A
BOD	mg/L	382±50.94	60±0.00	27.50±3.54	7.5±3.54	98
VSS	mg/L	462±8.2	210±34.57	40.33±7.07	13±0.47	97
TSS	mg/L	1452±14.2	376.7±26.7	65.33±4.71	23.33±2.83	98
Alkalinity	mg $CaCO_3$/L	153.39±105.69	284.4±3.85	362.67±8,33	281.33±8.08	-
Total hardness	mg $CaCO_3$/L	539.58±175.47	293.33±5.77	288.33±17.56	256.67±40.41	52
Calcium hardness	mg $CaCO_3$/L	468.13±262.28	143.33±20.82	170±10	193.33±5.77	59
Acidity	mg $CaCO_3$/L	33.095±11.94	14.44±1.92	40±3.46	34±2	-
Total coliforms	UFC·100 ml^{-1}	$9.5x10^7$	$4x10^6$	$13x10^5$	$11x10^3$	99
COD	mg/L	696.48±158.11	410,5±24.75	157.58±37.12	48.83±12.33	93
Inorganic phosphorus	mg/L	36.95±6.521	75.52±1.59	88.62±4.82	88.16±8.10	-
Nitrates (N-NO_3)	ppm	82.1±1.1	6.60±0.48	0.47±0.09	4.65±0.40	94

3.4 Kinetic Parameters

Kinetic parameters are shown in Table 3. The value of K_s corresponded to 229.12 mg · L^{-1}, which reveals good performance of activated sludge since it represents 32% of the average of COD. This value is similar to those reported by other authors [11], who obtained values of K_s between 338,009 and 181 mg · L^{-1} presenting a better performance during the months in which VSS were higher in the reactor.

Table 3. Determination of kinetic parameters

Parameter	Unit	This work	Ref. [11]
K_s	mg·L^{-1}	229.12	241.86
k	d^{-1}	2.12	0.645
K_d	d^{-1}	0.1495	0.051
Y	mg VSS ·mg COD^{-1}	0.345	0.4016
μ_{max}	d^{-1}	0.7315	0.2951

A single microorganism is able to remove as maximum 2.12 mg of substrate per day according to the maximum specific rate of substrate utilization (k) obtained in this experiment. The endogenous respiration coefficient (K_d) refers to cellular matter that suffers oxidation at any time during aerobic process inside the reactor. This parameter is 0.1495 d^{-1}, which establishes that approximately 15% of biomass in reactor is being oxidized per day, value higher compared to the study carried out by other authors [11], who obtained K_d values not higher than $0.07d^{-1}$.

Conclusions

The average residual water flow measured was 0.822 L/s, with a minimum and maximum hourly flow of 0.481 L/s and 1.173 L/s, respectively. The main source of pollutants corresponded to stables, which has highest concentrations of COD, DBO and fecal and total coliforms, which could be attributed to high concentrations of organic-livestock compounds such as cellulose and starch from plants and phosphates, sulfates, nitrates and nitrites products from animal metabolism. These last compounds were significant during the analyze of results, because these substances can interact directly with potassium dichromate in COD measurement, so it was possible to obtain a higher COD load than that obtained only by the degradation of matter by microorganisms in BOD. The treatment of activated sludge supplemented with an aerobic lagoon system was effective for the removal of pollutant load reaching values up to 93%, 98% and 99% in removal of COD, BOD and total coliforms respectively, which obey the minimum discharges established in resolution 0631 of 2015 for livestock, fish and domestic wastewater. The kinetic coefficients registered values similar to those described by other researches and suggest a good performance of activated sludge used in the treatment of wastewater, which validates the methodology for its activation (mixtures of highly contaminated wastewater from stables and fishpond water).

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References

[1] R. Haribowo, M. Yoshimura, M. Sekine, Tsuyoshi Imai, K. Yamamoto, T. Higuchi, A. Kanno, Behavior of Toxicity in River Basins Dominated by Residential Areas, *Contemporary Engineering Sciences*, **10** (2017), 305–315. https://doi.org/10.12988/ces.2017.7116

[2] Z. Wang, D. Shao, P. Westerhoff, Wastewater discharge impact on drinking water sources along the Yangtze River (China), *Science of the Total Environment*, **599–600** (2017), 1399–1407. https://doi.org/10.1016/j.scitotenv.2017.05.078

[3] A. Muñoz-Cruz, Caracterización y Tratamiento de Aguas Residuales, Universidad Autónoma del Estado de Hidalgo, 2008.

[4] T. Marras, A. Petroselli, F. Vessella, G. Damiani and B. Schirone, Noble Biomass : Restore , Recycle , Profit Using Cork Oak (Quercus suber L.), *Contemporary Engineering Sciences*, **8** (2014), 6495–6513. https://doi.org/10.12988/ams.2014.46455

[5] J. Essomba, J. Nsami, P. Desire, Belibi Belibi, G. M. Tagne and J. K. Mbadcam, Adsorption of Cadmium (II) Ions from Aqueous Solution onto Kaolinite and Metakaolinite, *Pure and Applied Chemical Sciences*, **2** (2014), 11–30. https://doi.org/10.12988/pacs.2014.31017

[6] C. Huang, M. Luo, Xue-Fang Chen, Lian Xiong, Xiao-Mei Li and Xin-De Chen, Recent advances and industrial viewpoint for biological treatment of wastewaters by oleaginous microorganisms, *Bioresource Technology*, **232** (2017), 398–407. https://doi.org/10.1016/j.biortech.2017.02.055

[7] R. Cristóvão, C. Gonçalves, Cidália M. Botelho, Ramiro J.E. Martins, J.M. Loureiro and R. Boaventura, Fish canning wastewater treatment by activated sludge : Application of factorial design optimization Biological treatment by activated sludge of fish canning wastewater, *Water Resources and Industry* **10** (2015), 29–38. https://doi.org/10.1016/j.wri.2015.03.001

[8] A. Colorado, M. Leal, E. Castillo and A. Gonzáles, Análisis microbiológico en el arranque de una planta de lodos activados, *XXII Congreso Nacional de Hidráulica*, 2012.

[9] Manual de Disposición de Aguas Residuales, Centro Panamericano de Ingeniería Sanitaria y Ciencias del Ambiente (CEPIS)/ Organización Panamericana de la Salud (OPS)/ Organización Mundial de la Salud, (1991).

[10] J. Romero, Tratamiento de aguas residuales teoria y principio de diseño, *Escuela Colombiana de Ingeniería,* (2000).

[11] N. Urbina-Suárez, J. Suárez-Gelvez and S. Pabón, Diseño e implementación de un sistema de tratamiento de agua residual para el frigorífico la frontera Ltda, Villa del Rosario, (2005).

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