Biologic Aerobic Reactor Flocairfp in the Piloto Plant: Removal of Contaminants from Wastewater in the Riachuelo My Father Jesus

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***Abstract*-This project aims to evaluate the efficiency of the modified aerobic biological reactor FLOCAIRFP for the removal of organic matter, nitrogen, and phosphorus in the water from the Quebrada Padre Jesus. This Quebrada receives discharge from domestic and livestock wastewater from human settlements located at its top. Two parallel reactors, with the first anoxic tank volume of 15% and the second with 10% anoxic volume, were worked. In reactors for continuous aeration and plastic filling where fixing bacteria remained, treatment flow was 0.1 ℓ / min for each. The operation during the stabilization phase reactors indicated that the removal of BOD5 in the reactors was only possible in 50% of study time, whereas nitrogen removal efficiencies were favorable in 55% of study time and biological phosphorus removal was favorable in 40% of the evaluated time.**

Keywords- Organic Matter; Nitrification; Denitrification; Biological Phosphorus Removal

I. INTRODUCTION

The Ravine Father Jesus (Quebrada Padre Jesus) is in the south Lindero of the Vivero of the Distrital University Francisco José de Caldas (Universidad Distrital Francisco José de Caldas, Bogotá, Colombia). Through its path, the Ravine receives discharge of untreated and/or partially-treated wastewater of domestic livestock activities, which leads to problems such as a reduction in the Ravine's aesthetic, an increase in odor problems, presence of vectors, and so on. To reduce, mitigate, or debug the pollution of the water it needs to be treated to remove physical, chemical, and biological by a series of processes and operations to improve the quality of the water. In this way, the disposal of the water into other bodies of water enables it to be reused in other economic activities [1, 2]. The current study aims to evaluate the efficiency of removal (from the contaminated water of the Ravine) of organic matter, total suspended solids, nitrogen and phosphorus using an aerobic biological reactor to flow piston-FLOCAIRFP, which has been previously submitted to the operation of sedimentation.

II. METHODOLOGY

The design of the biological reactors was realized based on the criteria established in the Regulations of the Sector of Drinking Water and Basic Sanitation, RAS 2000, title E. [3]. The difference between one reactor and another is the volume of the anoxic tank, which is in charge of removing nitrogen and phosphorus. For reactor I, 15% is the total volume of the tank. For reactor II, 10% is the total volume. The system's operation was based on the treatment scheme presented in the Fig. 1. The initial inoculation of mud was realized in a proportion of 30% of the total volume of the reactor, from the system wastewater treatment (SWT) that worked Zanjón of oxidation. Every 2 hours, the sedimented mud was recirculated from the settler 2 to the reactors, to keep the solids suspended in the liquid mixture [4, 5, 6].

Table 1 shows the parameters measured, the time of sampling, the frequency of the measurements, the type of samples, and the points of sampling.

The lab tests performed were COD, BOD_5, SST, total nitrogen, and total phosphorus [7, 8]. These were analyzed by the Antek Laboratory S.A., accredited by the IDEAM under rules NTC-ISO 17025 (Resolution No. 0379 of December 2007 and Resolution No. 0146 of May 2008), according to the procedures of sampling of the Standard Methods.

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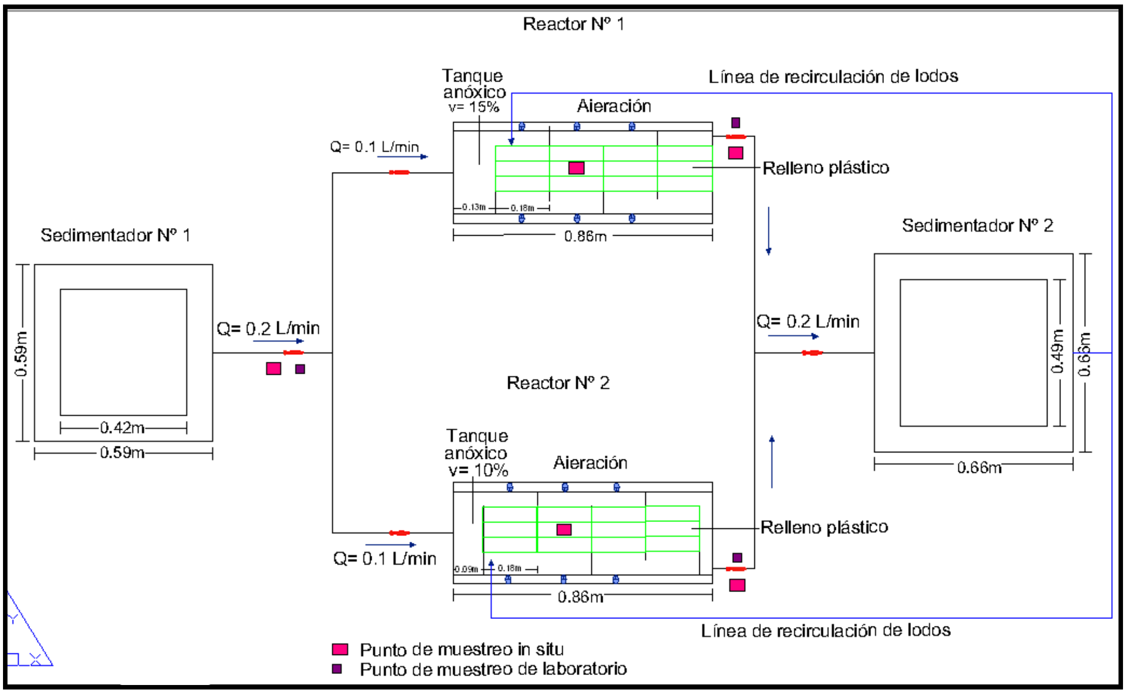

Fig. 1 Schematic of treatment in biological reactors

TABLE 1 MEASURED PARAMETERS AND FREQUENCY

PARAMETER		SAMPLED TIME		TYPE OF SAMPLE	SAMPLING POINTS		
		DAYS	FREQUENCY		Settler output 1	Within c / reactor	Output c / reactor
In-situ	pH	90	Every day, every 2 hours for 12 hours, for a total of 6 data per day	Spot-electrode	X	X	X
	Dissolved oxygen	90		Spot-electrode	X	X	X
	temperature	90		Spot-electrode	X	X	X
	conductivity	60		Spot-electrode	X	X	X
	total dissolved solids	60		Spot-electrode	X	X	X
Accredited laboratory Antek S.A.	CQO	34	Point sampling was conducted three times a week.	Punctual	X	*	X
	BOD_5	34		Punctual	X	*	X
	Total suspended solids	34		Punctual	X	*	X
	Total nitrogen	34		Punctual	X	*	X
	Total phosphorus	34		Punctual	X	*	X
Ensay	Sludge volume index	27	We performed two times per week	Punctual	*	*	X

III. RESULTS

Table 2 presents the average value of the parameters measured in the field. The phase of operation was between the fourth of January until the fourth of April of 2010.

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TABLE 2 AVERAGE OF THE MEASURED PARAMETERS IN THE SYSTEM

Parameter	units	Number of daily measurements	Number of tested	Total averaged data	Sampling point				
					I thirst Afluente	Within reactor 1	Reactor 1 Output	Within reactor 2	Reactor 2 Output
pH	units	6	90	540	7,26	7,52	7,54	7,50	7,51
Dissolved oxygen	mg/L	6	90	540	1,99	3,92	3,96	9,62	3,56
temperature	°C	6	90	540	16,50	16,23	16,23	16,55	16,62
conductivity	uc/cm	6	60	540	395,45	426,05	428,05	393,83	396,57
total dissolved solids	mg/L	6	60	540	197,63	213,24	214,96	195,74	198,57
CQO	mg/L	1	34	34	119,29	*	201,53	*	208,59
BOD	mg/L	1	34	34	66,32	*	125,00	*	111,97
Total suspended solids	mg/L	1	34	34	47,06	*	315,76	*	309,09
Total nitrogen	mg/L	1	34	34	7,13	*	8,05	*	8,34
Total phosphorus	mg/L	1	34	34	0,48	*	0,85	*	0,86

Source: Authors.

* No laboratory sampling was conducted within biological reactors.

A. Parameters in Situ

pH: it keeps an average of 7.5 units, indicating that during the operation of balance of the microbial consortium, appropriate conditions to develop and assimilate organic matter were present. Additionally, this pH level helps the process of nitrification (pH between 7.2 and 9.0 units) and desnitrification (pH between 6.5 and 7.5 units), according to the recommendation of reference [9, 10, 11, 12] for this type of treatment. Low pH can inhibit the growth of the nitrifying organisms and help the growth of organisms that interfere in the characteristics of the sludge's settling ability.

I. Dissolved oxygen: the dissolved oxygen keeps the reactors in aerobic conditions, which helps the fast microbial decomposition of the organic material and the mixing of wastewater with the microbial cells.

This promotes a thorough mix of the substratum with the microorganisms, and keeps the entire mass in suspension [4].

The dissolved oxygen in the reactors keeps, during most of the operation, an interval between 3.6 and 3.9 mg/L, allowing the microorganisms to have oxygen availability for metabolic activities and to assimilate into the organic matter. In one particular study realized [13, 14, 15], it was found that in order to remove nitrogen total-NT and phosphorus total-PT the wastewater keeps the optimal OD at 3 mg/L, getting a performance of 88.4% for NT and 89.5 % for PT.

This indicates that OD concentrations in the reactors assisted the removal processes of nitrogen and phosphorus.

II. Temperature: the temperature in the reactors maintained an average of 16°C, which is meant to aid the development of psychrophiles microorganisms (they develop in environments with temperatures between 12-18 ºC).

This range of temperature prevents the process of nitrification-denitrification and elimination of phosphorus from being done accurately, because this requires a minimum temperature of 20°C to develop the nitrifying organisms. In another study [16, 17], it was discovered that the temperature needed to be higher than 20°C to develop the nitrifying organisms.

The study N proves that when temperatures were above 20°C, the removal of nitrogen was 74% and the removal of phosphorus was 85%. With a temperature reduced to 18°C, the removal rate was also reduced to 67% for nitrogen and 70% for phosphorus.

III. Conductivity: electrical conductivity is a parameter compounded of the concentration of ions that are conductive in a solution. When higher amounts of salts, acids, or bases are present in a solution, the connectivity is higher. The substances dissolved in the water are associated with household wastewater disposal of high-charge solid waste [18].

The performance of the conductivity in the reactors maintained an interval between 390 and 420 µs/cm. These values show that there are a lot of substances dissolved in the water with an ion conductor. This is a consequence of the disposal of wastewater used in households and agricultural activities such as pig-breeding (these activities and others are performed at the top of the ravine).

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IV. Total Dissolved Solids (TDS): The total solids disposed are associated with the organic and inorganic material in the solution, and they are also associated with the conductivity. The performance of TDS in the reactors was between 190 and 214 mg/L; this is correlated to the increase in household and pig farming wastewater disposal.

B. Laboratory Parameters

I. Chemistry Demand of Oxygen (CQO): The CDO is a parameter that measures the quantity of substances dissolved or suspended in the water that are susceptible to be rusted by chemical media. This is therefore used to measure the level of pollution. Fig. 2 presents the result of the CQO measured in the reactors during the operation of balance.

It shows that it maintained an interval between 3 and 400 mg/L. The fluctuation is related to the variation in wastewater's pollution load.

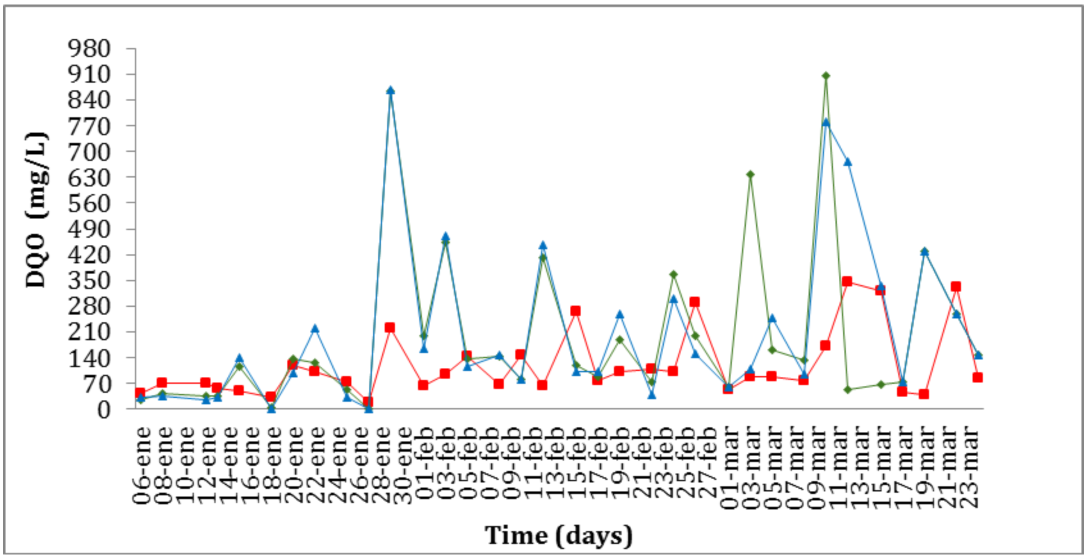

Fig. 2 Behavior of the chemical oxygen demand in bioreactors

II. Biochemical Oxygen Demand: BOD_5 is related to the measurement of microorganisms that consume dissolved oxygen in the biochemical oxidation process of organic matter. The purpose of biological treatment is to mineralize the soluble organic matter into carbon dioxide and water. However, any reactor can transform 100% of influent BOD, and a fraction of it will become additional cell mass due to cell growth.

Fig. 3 presents the result of the BOD_5 measured during the stabilizing operation. We conclude that the concentration of BOD_5 remained steady between 14 and 250 mg/L, with the fluctuation relating to the adaptation of the microorganisms and metabolization of BOD_5.

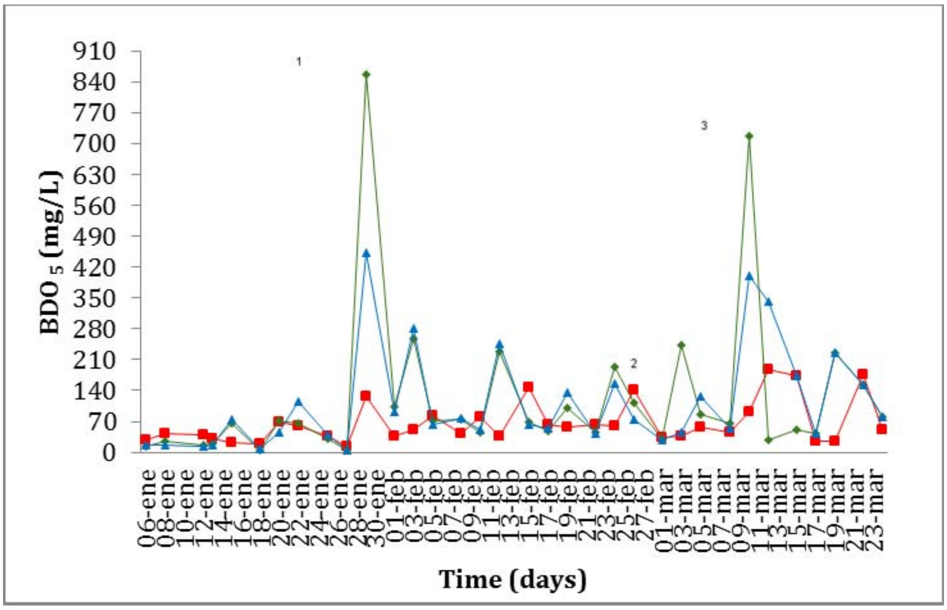

Fig. 3 Behavior of biochemical oxygen demand in bioreactors

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III. Total Suspended Solids (TSS): In the activated sludge process, organic matter entering the system is not eliminated, but is transformed into carbon dioxide, water, and new cells.

The following process occurs when there are optimal conditions: the microorganisms present in the reactor generate a polysaccharide gel, which is responsible for provoking agglomeration of these microorganisms in the microbial floc (called the biomass). After this, the treatment of aeration goes to a secondary clarifier, which separates the clear supernatant of the biomass and recirculates part of that biomass to the system of aeration. This aims to maximize the concentration in the reactor. Fig. 4 presents the performance of SST in the reactors; we can observe that the effluent of concentration of SST is present in an interval of 10 and 140 mg/L, since it comes from a treatment of primary sedimentation. The concentration of SST in the effluent of reactors was very variable, between 100 and 1660 mg/L. This is due to the sludge recirculation, which seeks to increase the time of residence of the substratum and also increase the biomass concentration in the reactors.

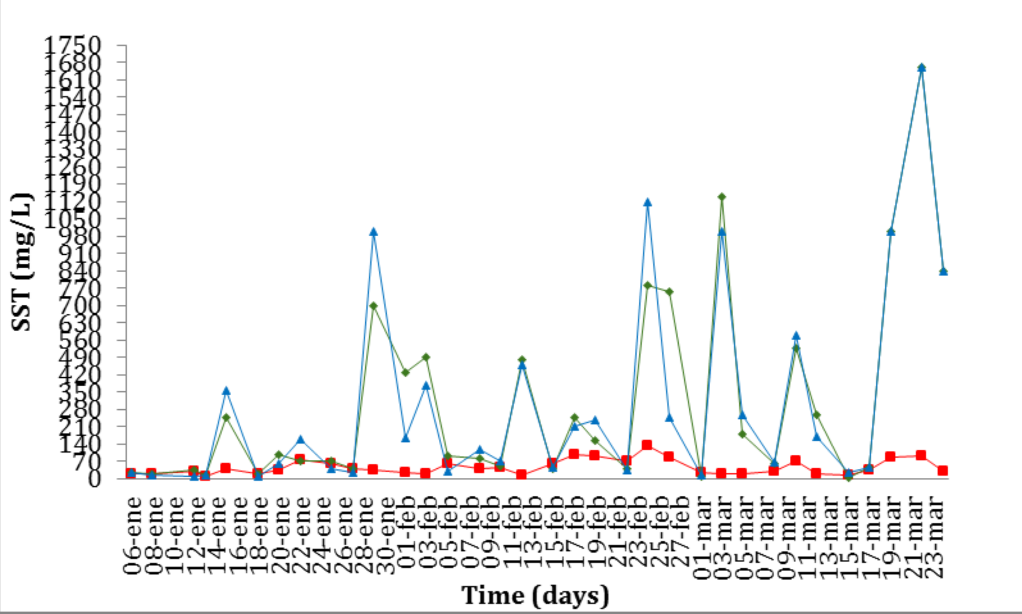

Fig. 4 Behavior of total suspended solids in biological reactors.

IV. Total Nitrogen: nitrogen can be withdrawn from the sewage water by the process of nitrification-denitrification in the anoxic and anaerobic phases. In the aerobic phase of conversion, bacterial species are involved. The first action of the bacteria of Nitrosomonas is to oxidate the ammoniac to nitrite. In the successive phase, the bacteria Nitrobacter oxidize nitrite to nitrate. Once these two phases are accomplished, the bacteria facultative aerobic heterotrophic, that in anoxic confitions are capable to use the nitrates as an electron acceptor, in case of oxygen dissolved, convert the atmospheric nitrogen nitrate (N_2). The performance of the nitrification process depends on a specific speed of nitrification with certain parameters such as: temperature; dissolved oxygen; pH; and the relation between organic matter and nitrogen. For this reason, the reactors' object of evaluation had several anoxic-aerobic steps with different volumes of anoxic tank. Fig. 5 presents the concentrations of total nitrogen throughout the experiment. We observed that in the affluent of concentration, nitrogen keeps an interval of 0.6 and 18 mg/L. In the output reactors, concentrations are highly variable (between 1 and 18 mg/L in reactor 2). This behavior is related to the variety in the concentration of water disposal and the water dilutions in the ravine made by rain.

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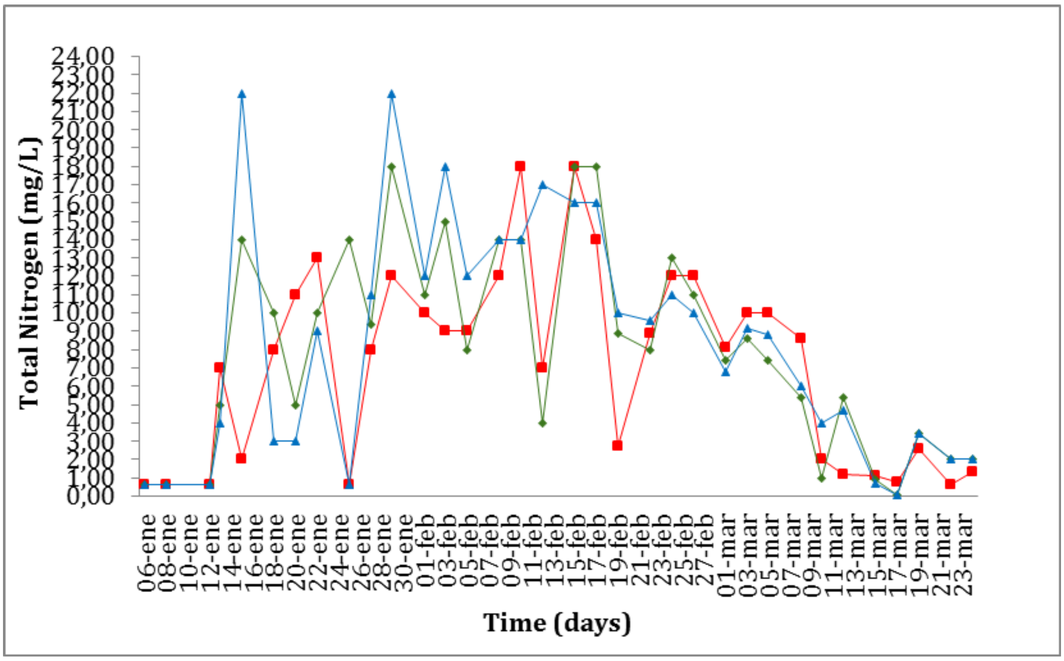

Fig. 5 Behavior of total nitrogen in biological reactors

In the above graph, we can see that when nitrification was satisfactory, and it was not high, the conditions in the system allowed for nitrification to occur. This behavior is a result of the stabilizing process. A specific study indicated that the accurate removal could take between 60 and 90 days of operation when the conditions in the reactors are stabilizing.

V. Total Phosphorus: phosphates can be eliminated from the water by the aerobic bacteria Acinetobacter. This bacteria accumulates the polyphosphates in the cells' tissues. Acinetobacter can assume an abundant quantity of phosphates, even bigger than the quantity needed for the synthesis of their own cells. The determining factors of the process of biologic elimination of phosphorus are: the nature and availability of the organic matter; the presence of OD throughout the process; the presence of nitrates during the anoxic phase; the pH; and the temperature. Fig. 6 suggests that phosphorus concentrations in the affluent maintain an interval of 0.1 and 1 mg/L. In the effluent of the reactors, the phosphorous concentrations remain steady between 0 and 5 mg/L in reactor 1 and between 0 and 6 mg/L in reactor 2.

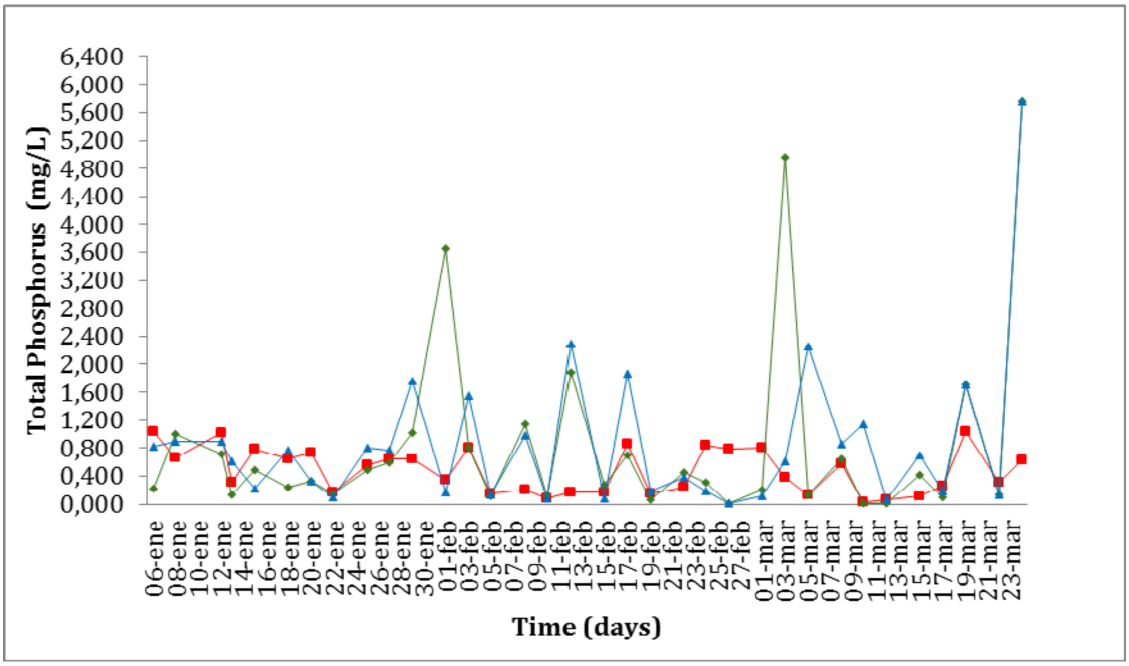

Fig. 6 Behavior of total phosphorus in biological reactors

It is not possible to realize the process of simultaneous elimination of nitrogen and phosphorus without generating an inhibition in the elimination of one of the two nutrients. This has been confirmed in the study [9], where it was seen that in

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simultaneous removal phases of N and P, the first phase resulted in an average removal of N of 53%, which decreased to 30% between the system of nitrifying bacteria and accumulating the phosphates adding phosphorus in the second phase of research. This shows a competence.

Availability of Nutrients: in systems of aerobic biological treatment, a proportion of nutrients BOD_5/N/P 100:5:1 should be maintained, with the objective that the microorganisms have the substratum needed for the development of metabolic activities. Table 3 presents the nutrient ratio in the biological reactor, taking the BOD_5 affluent, like the 100% that calculates the proportion of nutrients in the system, and evaluates whether it maintains the proportion 100:5:1. For the major part of the stabilizing phase of the reactors, the proportion BOD_5/N/P was over the recommended amount. For either one or both nutrients, this performance did not help in the process of biologic removal of nitrogen and phosphorus, because these concentrations in some cases generate growth in the reactor effluent. The presence of one of the nutrients in low proportions could slow down and limit biomass growth.

TABLE 3 AVAILABILITY OF NUTRIENTS IN THE EFFLUENT OF BIOLOGICAL REACTORS

	Concentration in the effluent of the reactors			**Relationship BOD_5: N: P 100: 5: 1**		
Date	**BOD_5 (mg/L)**	**N (mg/L)**	**P (mg/L)**	**BOD**	**N**	**P**
Jan-06	28	0,60	1,030	100,00	2,14	3,68
Jan-08	43	0,60	0,662	100,00	1,40	1,54
Jan 12	39	0,60	1,020	100,00	1,54	2,62
Jan 13	30	7,00	0,304	100,00	23,33	1,01
Jan 15	23	2,00	0,780	100,00	8,70	3,39
Jan 18	18	8,00	0,638	100,00	44,44	3,54
Jan 20	70	11,00	0,732	100,00	15,71	1,05
Jan 22	61	13,00	0,173	100,00	21,31	0,28
Jan 25	38	0,60	0,561	100,00	1,58	1,48
Jan 27	13	8,00	0,639	100,00	61,54	4,92
Jan 29	127	12,00	0,644	100,00	9,45	0,51
Feb-01	37	10,00	0,351	100,00	27,03	0,95
Feb-03	52	9,00	0,798	100,00	17,31	1,53
Feb-05	82	9,00	0,154	100,00	10,98	0,19
Feb-08	41	12,00	0,204	100,00	29,27	0,50
Feb-10	81	18,00	0,085	100,00	22,22	0,10
Feb-12	36	7,00	0,175	100,00	19,44	0,49
Feb-15	147	18,00	0,172	100,00	12,24	0,12
Feb-17	64	14,00	0,851	100,00	21,88	1,33
Feb-18	56	2,70	0,159	100,00	4,82	0,28
Feb-22	63	8,90	0,235	100,00	14,13	0,37
Feb-24	59	12,00	0,833	100,00	20,34	1,41
Feb-26	142	12,00	0,796	100,00	8,45	0,56
Mar-01	35	8,10	0,806	100,00	23,14	2,30
Mar-03	36	10,00	0,383	100,00	27,78	1,06
Mar-05	56	10,00	0,135	100,00	17,86	0,24
Mar-08	46	8,60	0,567	100,00	18,70	1,23
Mar-10	93	2,00	0,023	100,00	2,15	0,02
Mar-12	189	1,20	0,067	100,00	0,63	0,04
Mar-15	172	1,10	0,121	100,00	0,64	0,07

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Mar-17	26	0,80	0,263	100,00	3,08	1,01
Mar-19	25	2,60	1,030	100,00	10,40	4,12
Mar-22	176	0,60	0,302	100,00	0,34	0,17
Mar-24	51	1,30	0,622	100,00	2,55	1,22

Source: Authors

IV. CONCLUSIONS

In 50% of the study time (3 months), BOD_5 was removed in 50% of the time. In 34 samplings, getting removals between 40-80% in 55% of cases for reactor 1 and in 60% of cases for reactor 2 presents a negative rate of removal that is related to the inaccurate development of microorganism makers to assimilate organic matter, and with the sludge recirculation that is performed. The removal of SST was only possible in 17 % of the time of study for reactor 1, and in 26% for reactor 2, getting very low removals between 40-60% for the first reactor and 20-40% for the second reactor. The negative removal is associated with the process of biological treatment and the aerobic way in which the organic matter transforms into carbon dioxide, water and new cells, generating biomass or sludge. The effluent of the biological reactors then goes to the secondary sedimentation treatment.

The clear supernatant separates from the biomass and recirculates part of the biomass in the system of aeration. The performance of elimination of nitrogen was positive in 40% of the time of study, achieving removals over 30% in 33% of cases for the first reactor and 50% of cases for the second reactor.

The performance of biologic elimination of phosphorus was positive in 59% of the time evaluated for the first reactor, and 45% for the second reactor, achieving removals of 80-100% in 55% of cases for the first reactor and 53% of cases for the second reactor. However, in a particular study it was not possible to facilitate a process of simultaneous removal of nitrogen and phosphorus without generating a competence and an inhibition in the removal of one of the two nutrients. Nonetheless, the reactors showed that on some days it was possible to eliminate the two pollutants simultaneously. In the system, the conditions that helped in the process of biological removal of nitrogen and phosphorus were accurate; the pH in the reactors was between 6.5 and 8.0 units; the temperature was between 12 and 20 ºC; and the OD was kept at an interval between 2 and 4 mg/L.

In the occasions that presented removal of BOD_5, nitrogen and phosphorus in the reactors, the removals surpassed the expectations of the system of total treatment (Departure clarify 2 BOD_5 80%, N 30% and P 40%). This indicates that the reactors are effective and that the negative removals are related to the process of stabilizing. These results are in agreement with the process of stabilization; as indicated in a recent study [8], "Accurate removal can take between 60 and 90 days of operation, when the conditions in the reactors are stabilizing."

The most efficient reactor to remove organic matter, nitrogen, and phosphorus simultaneously was the first reactor (anoxic volume 15%), which was capable of achieving removals between 40-80% for BOD_5, 80-100% for phosphorus, and over 30% for nitrogen.

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