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Determination of Kinetic Coefficients for the Stabilization of the Organic Matter in Biological Reactors in a Piston Flow

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Abstract: The kinetic coefficients for stabilization of the organic matter are useful to stablish the internal functioning of the biological reactors and indicate if the initial reactor is suitable. The biologic reactor N°1 has a better functioning with a time of retention of 4.2 day in a flow of 0.05 L min^{-1} more the 10% of flow of recirculation, this; supported by the removal percentage and the biomass produced in the reactor that was of 38.46 mg L^{-1}. While for the biologic reactor N°2 we observed an efficiency of 78.5% but at the same time of retention and flow that the reactor 1 in this the biomass generated was of 28.69 mg L^{-1}.

Key words: Biological reactor, coefficients, DBO, kinetic, biomass, organic

INTRODUCTION

The waste water in the composition is composed by substracts of multicomponents (In several cases, the source of carbone is the sustract but an inorganic nutrient, an amino acid, vitamin a or any other component needed for cellular synthesis can be refered as a sustract in particular cases) is a mixture of components that could be reported as BOD or COD or COT and each of these components are presents in the water in different concentrations and remove according to a kinetic order, although in different speed, could present every time the substract reduce (Limit nutrient of growth) in the same proportion reduce the speed of remotion the origin is a point of inflexion in a removal curve. The kinetic phenomena and stoichiometric of the remotion of the substract, the growth of biomass and the consume of oxygen are fundamental and explanatory of the biological process that the has treatment of wastewater, it means the study of the kinetic, determine the speed to which microorganisms degrade an specific residue that provides the basic information needed to determine the accurate size of the aerobic biological reactors, anaerobic or hybrid. In all the treatment systems is important to control the environmental conditions that guaranty an optimal environment for the development of microorganisms but additionally should have enough time to stay to allow them reproduce, this time has a direct relation with the rate of growth and the speed at which the substrate degrades that make us calculate the kinetic coefficients (Lawrence and Carty, 1970; Critttenden *et al*., 2005).

The knowledge of the stabilization of the organic matter in the treatment of sewage water, presents through the description of the growth and the model most used is the Monod (Eckenfelder, 2000; Droste, 1997) whic relates the microbial growth with the substract limit, it means, describe the dynamic of the growth of a bacterial crops, only limit by the concentration of substratum (Eweis *et al*., 1998) it has a high dependence of the temperature of the water, pH, nutrients and the type of microbial consortium present (Crites and Technobanoglous, 1998; Metcalf and Eddy Inc., 2003; Ewis *et al*., 1999). For that reason this article is base on the determination of these kinetic coefficients with them we make a comparison of the experimental information and the theoretical information, this information stablish ranges of coefficients that vary according the characteristics of the raw wastewater that was submitted to the treatment.

After that presents an analysis of development of the biological reactor to give a criteria if it was or not accurate the design done to treat the waters of the river Padre de Jesus in Bogota, taking care that all the sewage water do not have the same characteristics either the composition

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either the dynamic of behaviour. Is important to mention that the kinetic coefficients not only are used to indicate if the design of reactors was the accurate those are also useful to know, the development of the biological process that happened in the reactors (Mandt and Bell, 1982).

MATERIALS AND METHODS

The determination of the kinetic coefficients using the methodology exposed by Metcalf and Eddy Inc (2003) who propose a model with linear regression for this propose. For this last is developed a mdel with the data of the substrate in the entrance (affluent) and in the exit (effluent) of the biologic reactor in terms of DBO_5 (mg L^{-1}), the quantity of biomass (SSV/L) and the time of cell retention (days) to calculate this last was taken many data like the maximum flow, medium and minimum in the operation of the plant of pilot scale (Table 1).

Table 1: Selected flow to determine the kinetic coefficients.

Period of time	Flow (Q)
June 02-June 15	0.05 L min^{-1}
June 16-June 25	0.1 L min^{-1}
June 26-June 30	0.2 L min^{-1}

Biological reactors a piston flow: In the Francisco Jose de Caldas District University in December 2009 is was built a treatment plant of combined wastewater (domestic and livestock) to a pilot scale that by physical and biological process, it was treated a section (0.2 L min^{-1}) of water of the ravine (small river) Padre de Jesus. The system was compound by a homogenizer tank of 500 L, then the water was conduct to the first tank primary clarifier by pipeline of 1½" PVC with an entrance flow and exit of 0.2 L min^{-1}. In the exit of the clarifier with the objective to relize a first fase of particle separation by physical processes, since this point the water was reallocated to two aerobic biological reactors to piston flow FLOCAIRFP (flocculation aerated plug flow), the entrance flow for each of them was de 0.1 L min^{-1} these had a system of sludge recirculation that after adapt keep the equilibrium of the system in terms of biomass, additionally the reactors had an Anoxic tank, one of them to 10% (biological reactor N°1) and the other 15% (Biological reactor N°2) for the remotion of Nitrogen and Phosphorus additionaly. Finally, the water passed a second silter to finish the process of clarifying and spill again in the channel of the creek. All the system worked during 6 month (Fig. 1).

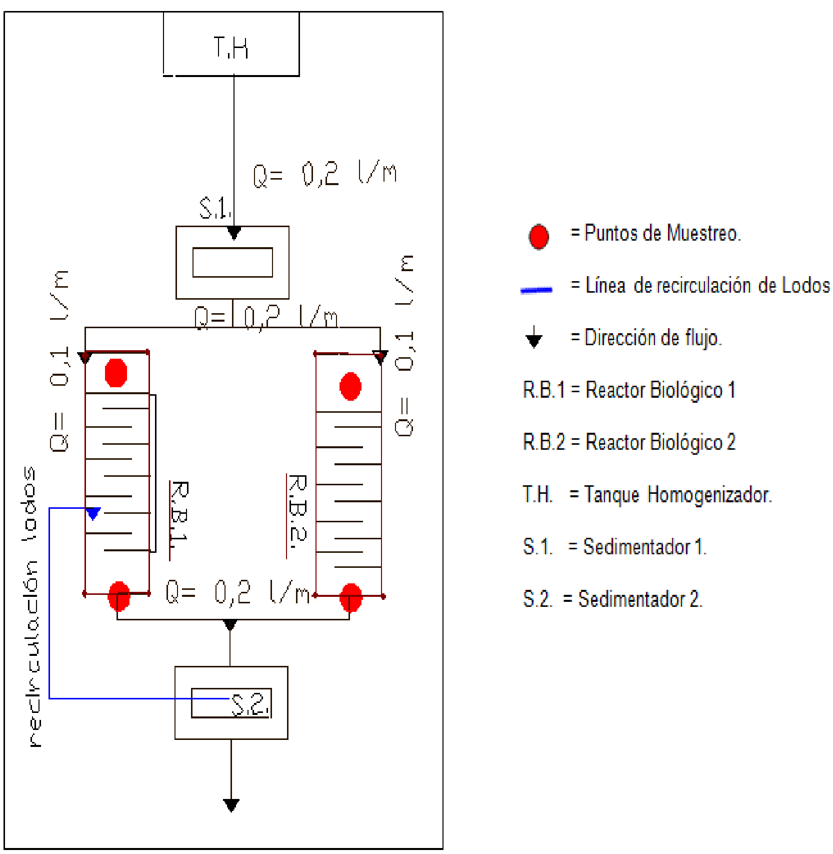

Fig. 1: Scheme Pilot Plant of wastewater treatment

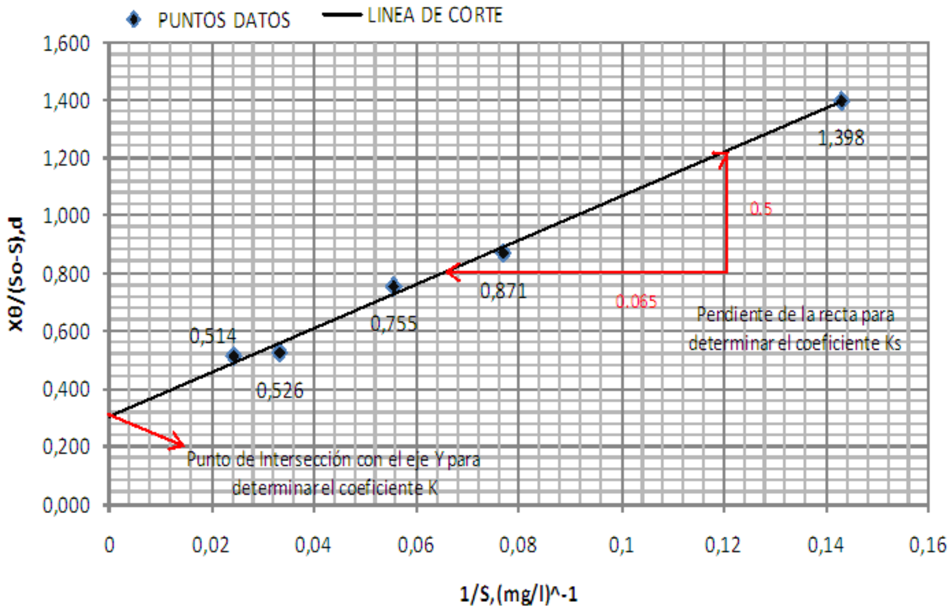

Fig. 2: Methodology to determine the coefficients K_S y K; Metcalf and Eddy, Wastewater Engineering Vol. 2, 2003

Table 2: Data calculated to determine K y K_S

1	2	3	4
So-S (mg L^{-1})	X⊖ (mg SSV/d^{-1})	X⊖/(So-S) (d)	1 S^{-1} (mg L^{-1})

Metcalf and Eddy, Wastewater Engineering Vol.2, 2003

Table 3: Data calculated to determine Y y K_d

1	2
1/⊖c d^{-1}	(So-S)/⊖X d^{-1}

Table 4: Typical kinetic coefficients to 20°C for muds activated

	Values	
Parameters	Interval	Typical
Y, mg SSV mg^{-1} BOD	0.4-0.8	0.6
Y, mg SSV mg^{-1} COD	0.25-0.4	0.4
K_d day^{-1}	0.025-0.075	0.06
K_s mg/L BOD	25-100	60
K_s mg/L COD	15-70	40
K day^{-1}	3-10	5

Metcalf and Eddy, Wastewater Engineering, Vol.2, 2003

Experimental determination of kinetic contants: Determination the constant of saturating substrate (K_s) and the maximum rate of use of the substract. With the data of the initial substract of affluent (S_O), exit substratum or effluent (S), concentration of biomass (X) and time of cell retention ($\ominus_c$), made a table to calculate in base of this equation (Table 2):

$$\frac{X\theta}{So-S} = \frac{K_s}{k}\frac{1}{S} + \frac{1}{k}$$

(Metcalf and Eddy Inc., 2003) at this way: Once obtained the values of the variables presented before, it was represented graphically the relation between (X⊖/S_o-S) with respect to (1 S^{-1}) in that one the intersection point with the ordinate axis correspond the value of K and the value of slope of the line obtained by the graphic corresponded to the value of K_s K^{-1} that later founded the value of coefficient K_s (Fig. 2).

Determination of the conversion coefficients of the substrate in cell mass(Y) and endogenous decomposition (K_d): To determine these coefficients at the same way was built a table with variables presented in Table 3, taking care of the values So, S, X y $\ominus_c$ and using the following equation:

$$\frac{1}{\theta c} = -y\frac{rsu}{X} - k_d$$

(Metcalf and Eddy Inc., 2003). Once obtained the values of the following variables presented in the last table, presented graphically the relation between (1/$\ominus_c$) respect to ((So-S)/⊖X). In the graphic the cutoff with the axis Y correspond to the value of K_d and the value of the slope of the line corresponded to the value of Y (Fig. 3).

Comparison of the coefficients determined and the values reported in the literature: With the results obtained by the kinetic coefficients, realized a comparison with the values stablished and the values presented in the bibliography taking care principally the ranges presented in Table 4-7 for domestic sewage water and according to the speech of several actors, this last with the objective to

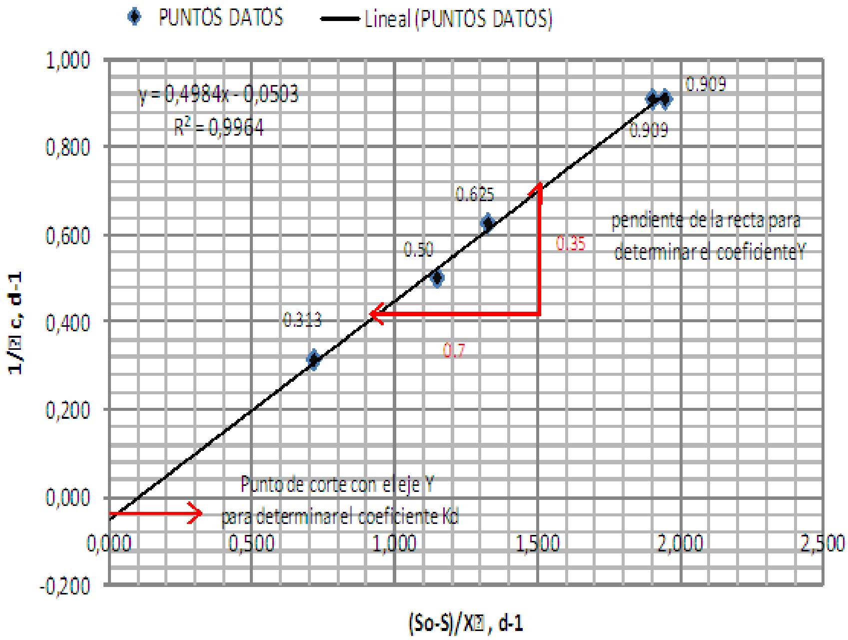

Fig. 3: Methodology to determine the coefficients K_d y Y; Wastewater Engineering, Vol. 2, 2003

Table 5: kinetic coefficients for the biological aerobic treatment in several substratum

Substratum	Y mg SSV mg^{-1} substratum	µ MAX d^{-1}	K d^{-1}	K_s (mg L^{-1})	K_d d^{-1}	Base of coefficient
Domestic waste	0.5	-	-	-	0.55	BOD
Domestic waste	0.67	13.2	-	-	0.048	BOD
Domestic waste	0.5	3.84	26.4	120	0.06	BOD
Domestic waste	0.67	3.75	5.7	22	0.07	COD
Domestic waste	0.67	2.45	5.6	22	0.07	COD
Skimmed milk	0.48	1.26	5.1	100	0.045	BOD
Glucose	0.42	1.95	3	355	0.087	BOD
Glucose	0.59	6.24	3.3	-	-	BOD
Peptona	0.43	5.05	14.5	65	-	BOD
Glucose-Peptona	0.49	0.35	10.3	-	-	BOD
Gaseous waste	0.35	-	1	0.31	0.031	COD
Synthetic waste	0.65	-	-	-	0.18	BOD
Pulp and Paper	0.47	-	-	-	0.2	BOD
Shrimp processing	0.5	-	-	85.5	1.6	BOD
Municipal wastewater	0.35-0.45	-	-	25-100	0.05-0.10	COD
Matadero	0.41	-	0.67	150	0.04	COD
Soya	0.74	-	16.2	355	0.14	BOD

Jairo Romero, waste wáter treatment, theory and principles of design 2004

Table 6: Kinetic coefficients intervals as Metcalf and Eddy

Experimental Reactor values No. 1

UNIT	So mg L^{-1} BOD5	S mg L^{-1} BOD5	θ = θc (d)	X, mg SST L^{-1}
1	315	30	4.2	71.5
2	47.75	24.5	2.1	63.25
3	29.25	15.25	1	60.25

Parameter	Range
K mg mg^{-1} d	5-10
K_s mg L^{-1}	100
Y	0.5-0.6
k_d d^{-1}	0.05

Metcalf and Eddy, Wastewater Engineering, Vol. 2, 2003

verify that the values of the constants determined in the current proyect were in the stablished ranges for this type of sewage water.

Table 7: Kinetic Coefficients of domestic wastewater

µ MAX	K_s (mg L^{-1})	Y	K_d (mg L^{-1})	Base
0.6	12-80	0.38-0.67	0.01-0.014	BOD (22)
1.7	43-223	0.31-0.35	0.016-0.068	COD
6.0	100	0.5-0.67	0.048-0.55	BOD (18)
3.75	22	0.67	0.07	COD
1.43-13.2	25-100	0.42-0.75	0.04-0.075	BOD (24)
3.2-3.75	22-60	0.4-0.67	0.07-0.09	COD

Manuel Gil, dynamic model of the secondary process of depuration of urban wastewater, 1998

One research about the dynamic model of the secondary process of depuration of urban sewage water, presents range of the coefficients in the process of depuration of sewage water, presented in Table 4 (Rodriguez, 1998, 2005), determined the kinetic coefficients for an aerobic reactor in a laboratory scale with average data took during the operation of this these data were S_o (substrate in the afluent mgDBO$_5$/L), S (substrate in the effluent mgDBO$_5$/L) and X (Concentration of Biomass in the reactor mg SSV/L) (Table 7).

RESULTS AND DISCUSSION

Biological reactor No. 1: The calculations of the coefficients K y K_S. For the Biologic reactor No. 1, the determination of these coefficients was done and show in Table 8, there were several variables of affluent and effluent substrate, the time of hydraulic and cell retention and biomass.

Making the graphics of the values according to the kinetic model of Monod (Fig. 4) has a conclution that the values of the coefficients for the biologic reactor No. 1 those are K de 7.41 day^{-1} y K_S de 119.82 mg L^{-1}.

Para el calculo de los coeficientes Y y K_d, se utilizaron los siguientes datos (Table 9). Making the graphic the values according to the kinetic model of Monod (Fig. 5), obtained that the values of the coefficients for the biological reactor No.1 which are Y of 0.60 mg SSV mg^{-1} Sustrato y K_d de 0.83 day^{-1}.

Biological reactor No. 2: The calculations of the coefficients K y K_S for the biologic reactor N°2, the determination of these coefficients are in Table 10, there were several variables of affluent and effluent substrate, the hydraulic retention time and and cell and biomass (Table 11).

Making the graphics of the values according to the kinetic model of Monod, Figure 6 show the values of coefficients for the biological reactor No. 1 which are K of 6.17 day^{-1} y K_S de 61.49 mg L^{-1}.

To calculate the coefficients Y y K_d were used the following data (Table 12) Making the graphics of the values according to the kinetic model of Monod, Figure 7 show the values of the coefficients for the biological reactor No. 1 which are Y of 0.43 mg SSV mg^{-1} Sustrato y K_d de 0.795 day^{-1}.

According to the results obtained by experiment the coefficients K de 7.41 day^{-1} (according to the range of literature 2-10 day^{-1}) (Crites and Technobanoglous, 1998; Metcalf and Eddy Inc., 2003) y K_S de 119.82 mg L^{-1} (according to the range of literature 25 a 120 mg L^{-1} BOD). For the biological reactor No. 1, we realize that both are in the range recommended for sewage water of domestic type (Finamore, 1999); about the coefficient K_S, compare to the typical values for the process of active mud, we realize that in biological terms there is an accurate relation between the speed of growth of microorganisms

Table 8: Values Average values of experimental data for reactor N°1

UNIDAD	So-S mg L^{-1}	xθ, mg SSv/d/1	xθ/(So-S), d	1 S^{-1}, (mg/1)$^{-1}$
1	285000	32500	0.114	0.033
2	23250	14375	0.618	0.041
3	14000	6847	0.489	0.066

Table 9: Kinetic coefficients Y y K_d for the reactor No. 1

UNIT	1/θc, d^{-1}	So-S/θX, d^{-1}
1	0.240	0.957
2	0.480	0.176
3	0.960	0.223

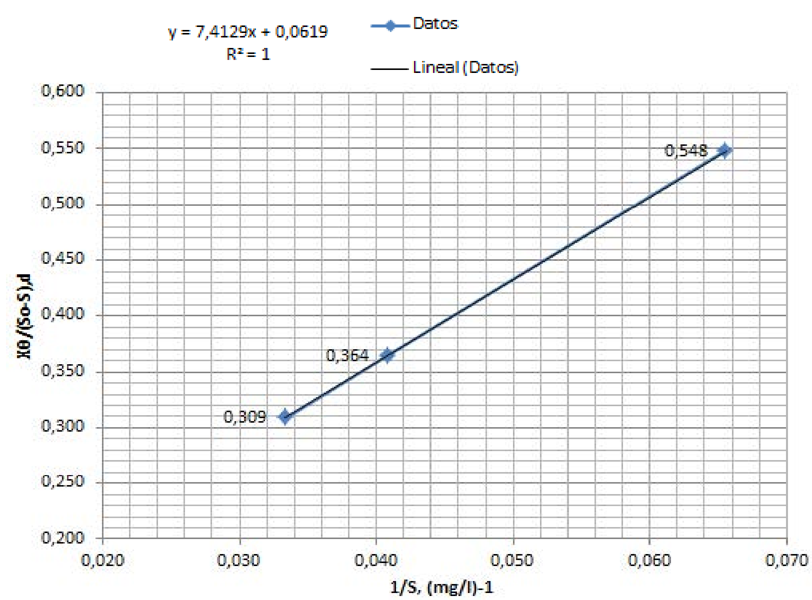

Fig. 4: Graphic representation of results of K_S y K

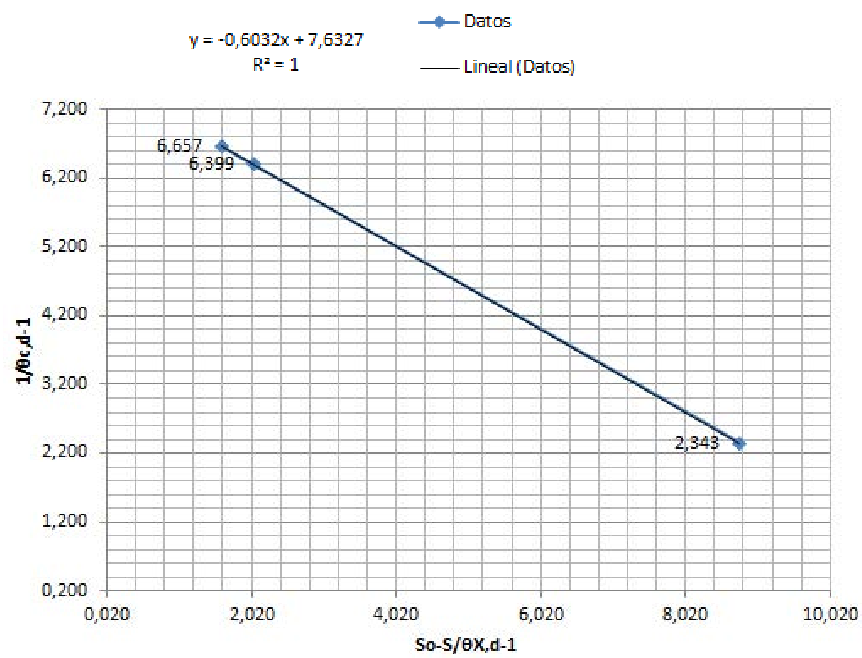

Fig. 5: Graphical representation of results graphical representation of results of K_d y Y

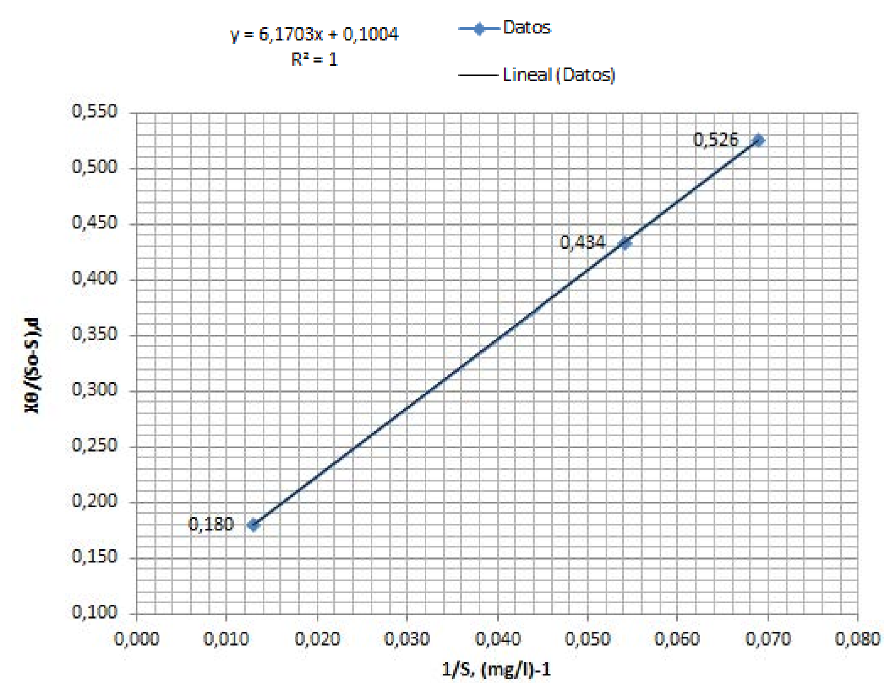

Fig. 6: Graphical representation of results of K_S y K

and the concentration of substrate in the reactor that stablish with the percent of removal in this reactor that is over the 80% with a time of hydraulic retention time of 2.29 day. For the biological reactor No. 1 in terms of the kinetic coefficients K_d de 0.83 day^{-1} (according to literature interval 0.025-0.075 d^{-1}) and Y of 0.60 mg SSV mg^{-1} BOD (according to literature interval 0.4-0.8 mg SSV mg^{-1} DBO; the coefficient K_d is out the

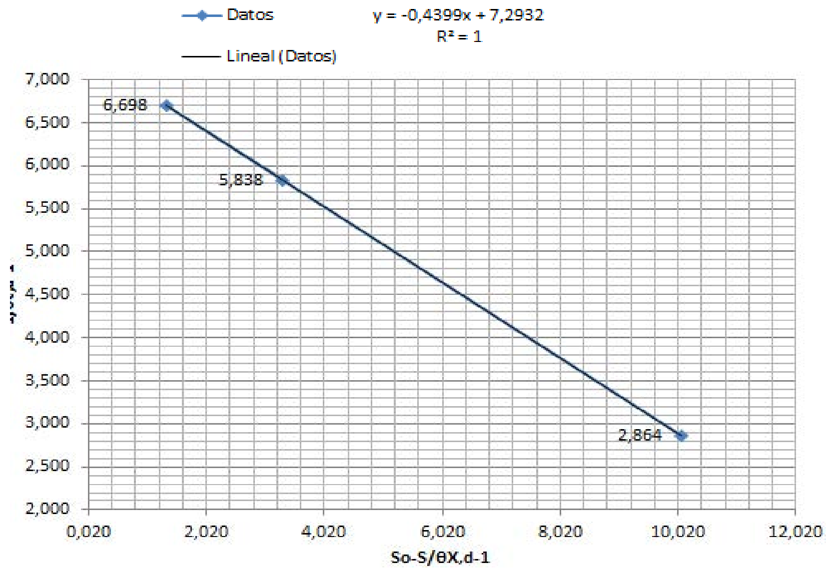

Fig. 7: Graphical representation of results of K_d y Y

Table 10: Average values of experimental data for the reactor N°2

Experimental Reactor values 2

UNIT	So mg L^{-1} BOD_5	S mg L^{-1} BOD5	θ = θc, d	X, mg SST/L
1	358.5	77	4.2	61.5
2	62.5	18.5	2.1	143
3	27.75	14.5	1	35.25

Table 11: Values average values of experimental data for react

UNIDAD	So-S mg L^{-1}	x mg SSv/d/1	x mg (So-S), d	1 S^{-1} $(mg/L)^{-1}$
1	281500	27955	0.099	0.013
2	44000	32500	0.739	0.054
3	13250	4006	0.302	0.069

Table 12: Kinetic coefficients Y y K_d for the reactor No. 2

UNIT	1/θc, d^{-1}	So-S/θX, d^{-1}
1	0.240	1.099
2	0.480	0.148
3	0.960	0.361

range stablished by Melcaft and Eddy but researchers like Romero, stablish a superior range that contains the value calculated by the model applied in this research. The value of Y means that the substrate conversion in cellular mass, presented in an optimal interval with a tendency is possible to find in some research related to this theme (Finamore, 1999; Liu *et al*., 2008) also this value shows the optimal use of the substract in the reactor to produce biomass. This last is an evidence when we calculate the specific rate of microbial growth (k×Y) which has a result of 1.06 day^{-1}, this value is in the stablish range in the theory and shows that exist not only a good relation between the values of coefficient k and Y, the coefficient K shows that happened a consume of substratum and the value of Y shows that this was consumed to make cellular mass (Rodriguez, 1998, 2005; Nodal, 2001; Crittenden *et al*., 2005).

For the biological reactor N°2, the experimental values of the coefficients of K de 6.17 day^{-1} (according to literature interval 2-10 day^{-1}) and K_S de 61.49 mg L^{-1} (according to literature interval 25 a 120 mg L^{-1} DBO); the rate of use the substratum K of 6.17 determined by the kinetic exposed by Monod, there we observe a relation between the biomass, measured as total suspended solids and the time of cell retention; compared with a reduction of rganic matter reflect in the substratum; it means if the organic matter is reduced considerably will be more production of biomass in the reactor that guaranty the good production of mud and microorganisms at the moment of each recirculation. By the other side the kinetic coefficient K_S, using the kinetic of Monod is in the range exposed in the literature in terms of BOD with a value of 61.49 mg L^{-1} taking care that the ranges are very wide, we would understand that the speed that the microorganisms join the organic matter is directly proportional with a reduction of BOD.

The value founded for the coefficient K_s is the optimal, it means that there is an equilibrium between the speed of microorganisms to consume the organic matter and the generation of microorganisms, it means these are in the stationary phase, if reffered the the growth curve, what it is meant as a good behavior within the biological reactor (Lawrence and Carty, 1970; Polo *et al*., 2008). For the biological reactor No. 2 in terms of kinetic coefficients K_d of 0.795 day^{-1} (according to literature interval 0.025-0.075 day^{-1}) and Y of 0.43 mg SSV mg^{-1} BOD (according to literature interval 0.4-0.8 mg SSV mg^{-1} BOD); the coefficient K_d, corresponds to the endogenous decomposition that obtained a value of 0.795, value that is not in the range proposed in the literature, this coefficient show us a direct relation and proportional between the bacteria death and the consume of themselves in the reactor was not much inside it.

This value suppose that there is not any remarkable activity between the alive bacteria using the as food the death bacteria to generate the new biomass, surely the lack of substratum at this point generates inside the reactor a faster mortality of the microorganisms, this result does not suppose the deathof microorganisms but cause the value is so far the optimal value, it reflects some of endogenous metabolism. At the end according to the value obtained for the coefficient Y that was of 0.43 day^{-1}, a value that although is not optimal is in the range planned in the literature and could relate with the value obtained in the substrate utilization rate, cause this coefficient indicates the relation between consume of substrate and biomass formation in the reactor.

CONCLUSION

According to the last, could stablish that the biological reactor N°1 has a better functioning with time of retention of 4.2 day a flow rate of 0.05 L min^{-1} plus the 10% of recirculation flow, this; supported by the percent of remotion and the biomass produced in the reactor was 38.46 mg L^{-1}. While for the biologic reactor N°2 observed an efficiency of 78.5% but at the same time of retention and the flow that the reactor 1 in this the biomass generated was of 28.69 mg L^{-1}. The evaluation realized to both reactors reflected that the coefficients found in the range stablished by similar research applicable without. But one coefficient that was K_d (endogenous decomposition) for two reactors was far that indicates that could generate an imbalance when the microorganisms took the death cells as source of food.

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